# AN ANALYSIS OF WEIGHT GAIN IN PREGNANCY IN IRISH WOMEN USING AN ANTROPOMETRIC INDEX

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David P. Norton

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## ABSTRACT

A cross-sectional analysis of weight gain during pregnancy was performed, using data from 13,000 pregnancies included in the Rotunda Study, in Dublin, Ireland. Weight increase from ten weeks to forty weeks was 12.4 kg. The body mass index (BMI=wt./ht.2) was next implemented to examine weight gain from a new perspective. Increase in BMI from ten to forty weeks in the whole population was 0.47(gr./cm.2). The population was subdivided into three weight groups based on presenting body mass, and these groups were compared for overall increase in BMI, as well as rate of change throughout pregnancy. "Optimum" and "suboptimum" outcome (based on birthweight) were investigated, within the medium weight group. Smoking and non-smoking women were compared in a similar manner. The BMI seems a useful and simple tool for examining questions of weight gain during pregnancy.

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# PART I

# INTRODUCTION

## Chapter 1

The goal of this study is to provide a new and different method of investigating the question of maternal weight gain in pregnancy. The Rotunda Study, which is a large obstetrical research project being conducted at Trinity College in Dublin, in conjunction with the Rotunda Maternity Hospital, provides an opportunity to examine data from a group of almost 13,000 obstetrical patients who were followed at the Rotunda Hospital throughout their pregnancy. The availability of the computer system at Trinity College made such a project feasible.

There is a fair amount of available literature encompassing various aspects of weight gain in pregnancy. Investigators have not only looked at how much a woman gains during gestation, but also at clinical factors which affect and are affected by maternal weight gain. A fairly complete survey of the recent literature concerning these matters is included in this study.

In addition to examining actual weight gain over the course of pregnancy, this study also implements an anthropometric index known as the body mass index. This is, as far as we can tell, the first time that the change in an anthropome tric index has been followed over pregnancy. The particular index used is equal to the weight divided by the square of the height. The use of the index in other anthropometric studies is also discussed in the survey of the literature.

A major issue in the research involving weight gain during pregnancy has been the role of the size of the woman in determining weight gain. It is hoped that the use of the body mass index will provide a new approach to this question by taking into account both the height and weight of the women studied.

Two other important issues will be examined. The first is the question of an association between weight gain during pregnancy and prematurity, or low birth weight. Both the overall body mass increase and the pattern of change in body mass will be investigated in light of the birthweight of the infant. Secondly, the issue of smoking in pregnancy will be addressed. As will be noted in the literature survey, smoking has been associated in the past with both poor weight gain during pregnancy, and lower birthweight. By comparing change in body mass index in smoking and non-smoking women, it is hoped that the present study will offer a new perspective on this issue.

# PART II

# SURVEY OF THE LITERATURE

## Chapter 2

## REVIEW OF STUDIES OF WEIGHT GAIN

The issue of how much weight a woman should gain in pregnancy is one which has been investigated a number of times, but a definitive answer remains unclear. Hytten and Leitch, in their book "The Physiology of Human Pregnancy"(15), mention thirty-five papers produced up to 1971, and there have since been a couple more significant investigations. One of the earliest accounts of an obstetrician dealing with this matter is that of Sir Richard Croft, physician of Princess Charlotte, who kept her on a "low diet" during her pregnancy, which may have resulted in the stillbirth of her son in 1817.(15) Prochownik, in the late 1800's, fostered the idea of restricted weight gain to facilitate easier delivery. He was concerned with delivery of live babies from women with contracted pelves, and also with restriction of weight gain in obese women.(15)

Humphreys(14), in 1954, undertook one of the first fairly well-controlled studies of weight gain in pregnancy. He looked at "normal" healthy women, without preeclampsia, having normal babies. He examined primiparas and multiparas separately, and calculated weight gain from twelve weeks. The study was done immediately post-war, such that maternal diet was "war-time rationing." Of the 5265 primips in the study, the mean weight gain from twelve weeks was 11.7 kg, with a standard deviation of 3.8 kg. Multips (474) showed an an average gain of 10.7 kg, also with a standard deviation of 3.8 kg.

Thomson and Billewicz(40), in 1957, examined 4214 cases of women delivering at the Aberdeen Maternity Hospital, in Scotland, from 1949 to 1954. They looked only at primiparas, and excluded multiple pregnancies. The women were divided into three clinical groups- preeclampsia with albuminuria (6.5%), women with other hypertensive complications (mostly preeclamptics without albuminuria--25.4%), and those without hypertensive complications (68.1%). From their data they derived curves of average weight for gestational age from thirteen to thirty-eight weeks for each of the clinical groups. (See figure #1) Normotensive women were found to have an average gain of 21.9 lbs. for the period 13-36 weeks. To this they added 3.2 lbs. for 36-40 weeks. and 2.5 lbs. for the first trimester (taken from Chesley, 1944)-- for a total of 27.6 lbs (12.5 kg) average weight gain in term pregnancies. The figure for the three clinical groups combined was slightly higher, at 29.6 lbs. (13.4 kg.) in pregnancies going to term.

Nyirjesy(30), in 1968, conducted a very large study on maternal weight gain. He selected his subjects from 89,258 women who delivered in twenty-two naval hospitals arould the states between 1964 and 1966. He chose only primiparas, and of these used only patients with forty week gestations. 97.5% of the women had four or more recorded antenatal visits. Weight gain was calculated from the "non-pregnant weight," although there is no mention of how that weight was obtained--presumably the information was asked of the patient at her first antenatal visit. In terms of dietary restriction, it was "...assumed an effort by the obstetrician was made to limit the patients' weight gain to about twenty pounds." The mean total weight gain was 9.95 kg, with a standard devia-

tion of 3.77 kg. In the report, Nyirjesy notes that with a standard deviation of this size, only patients with weight gain less than 5.31 kg, or greater than 38.5 kg could be considered "statistically abnormal."

Another study which appeared in 1968 is that of Eastman and Jackson(8). Their investigation was taken from 25,154 pregnancies between January 1954 and December 1961. Gestations included were between 39 and 42 weeks. Subjects were deleted from the study if accurate information about weight gain was not available. Also deleted were all fetal deaths, multiple pregnancies, patients with diabetes or toxemia. A total of 11,191 subjects were then actually included. Total weight gain was defined as weight at the last visit (within two weeks of delivery) minus pre-conception weight "...as stated by the gravida." Mean total weight gain was 22.1 lbs. in white women, 20.5 lbs. in black women.

In 1971, Hytten and Leitch(15) published a book called "The Physiology of Human Pregnancy." In this book, there is a very comprehensive review of weight gain studies done up to that time. In reviewing the earlier studies, they note three important problems which cloud most investigations of weight gain. The first of these is manipulation of diet. There is often no indication in the reports of diets of the women involved, whether their food intake was influenced by obstetricians aiming for some "optimal weight gain," or whether any local trends or diet fads may have influenced total weight gain.

A second problem in many of the earlier studies is that there is often incomplete knowledge of health of the subjects. They note that abnormal pregnancies should be deleted if one is concerned with "normal

weight gain." To do so, one needs fairly complete information on the present and past health of the women studied. They note that it is often only possible to identify abnormal pregnancies retrospectively, but state that records should be kept such that this is indeed possible.

The final problem mentioned by Hytten and Leitch is the method of estimation of weight gain in early pregnancy. In many of the studies it is not made clear when the initial weight measurement was, or from what point total weight gain is calculated. Often weight gain is calculated from "stated" prepregnancy weight, which is hardly accurate. In some studies, a "standard" weight gain up to some point in early pregnancy is used.

In their own study Hytten and Leitch investigated women delivering at the Aberdeen Hospital in Scotland between 1950 and 1955. They looked at primiparas between 20 and 29 years of age, who were less than 160 cm tall. They included women who were of good or excellent health and physique, who delivered during their 39th, 40th or 41st week of pregnancy. Of the 746 women found fitting this description, 486 had no "clinical abnormalities." Such abnormalities included threatened abortion, antepartum hemorrhage, preeclampsia, hypertension and perinatal death. There was no attempt with these women to regulate weight gain by dieting. Since length of pregnancy varied between 39 and 41 weeks, they calculated "average weekly gain," which was 0.41-0.45kg, which would mean a total gain of 8.6 kg over 20 weeks. They note that this is comparable to weight gain in the second half of pregnancy as determined in a number of other studies, including that of Thomson and Billewicz(40),

mentioned earlier. They also point out that even in this highly select group of patients, range of weight gain was quite high.

Hytten and Leitch were not able to provide data for weight gain during the first half of pregnancy, but using the studies of Thomson and Billewicz', they did derive a table of weight gain for certain points in pregnancy, as follows:

| Week | Gain in Grams | (Lbs.) |
|---|---|---|
| 10 | 650 | 1.5 |
| 20 | 4000 | 9.0 |
| 30 | 8500 | 19.0 |
| 40 | 12500 | 27.5 |

## Chapter 3

## COMPONENTS OF WEIGHT GAIN

Hytten and Leitch(15) also looked at the components of the weight gained by woman in pregnancy. They calculated the average weight of the products of conception and other obvious components of weight gain. The breakdown of the components at term is as follows:

| | |
|---|---|
| fetus | 3000 gr. |
| placenta | 650 gr. |
| liquor amnii | 800 gr. |
| increase in uterine size | 900 gr. |
| increase in breast size | 405 gr. |
| increase in maternal blood | 1250 gr. |
| Total | 7300 gr. |

This leaves 5200 grams of the weight gain unaccounted for. In "Maternal Nutrition and the Course of Pregnancy"(23), put out by the U.S. National Academy of Sciences, it is noted that there is a one to two kilogram excess water gain right before term, but this still leaves about four kilograms unexplained water-free gain. This was formerly thought to be an increase in maternal protein,but this publication notes that a sizeable increase in protein would have to be accompanied by an increase in body water. Except in the case of frank edema, the only increase in body water is that noted right before term. Fat, then, is thought to be the main component of this "unexplained" weight gain.

Hytten and Leitch agree that fat is most likely a major component of weight gain. They note that in societies where nutritional status is not a problem, this fat remains only in depot. If, however, food is scarce in the last half of pregnancy, or the woman is doing heavy work till term, this fat can be drawn upon to satisfy energy needs in the last half of pregnancy, or during lactation.

In "Maternal Nutrition and the Course of Pregnancy"(15), fat storage is described as occuring at a rapid rate before midpregnancy, at which time it slows down, and ceases before term. A study is quoted (Taggart, et.al.,(36))which notes increases in skin fold thickness from ten to thirty weeks on the abdomen, back and upper thigh.

There has been some research investigating the mechanism for fat storage in pregnancy. "Maternal Nutrition and the Course of Pregnancy"(23) mentions one study that gave evidence of promotion of fat storage via progesterone. They speak of a possible "lipostat" in the hypothalmus, influenced by increased levels of circulating progesterone during pregnancy. It is thought that this added fat can be lost after pregnancy (if not used as a an energy source), when the decrease in progesterone would allow the "lipostat" to revert to its usual non-pregnant level.

In another study by Hytten, et. al.(15), there was some evidence that the components of weight gain may vary, depending upon a woman's initial weight and height conditions. They noted a large gain in water in women who were initially heavier for their height, and a larger portion of "dry-weight" gain in thinner women. They thus infer that pregnancy may have a "leveling" effect on the relative amount of body fat.

Eastman and Jackson(8) also make estimates of the various components of pregnancy weight gain. They estimate that the fetus weighs and average of 7.5 lbs., the placenta 1.0 lbs., uterine weight increase 2.0 lbs., and blood volume 3.0 lbs. This comes to a total of 14 lbs., and Eastman and Jackson note that any weight gain significantly below this amount would be a drain on maternal tissues. They do not, however, indicate how these estimates are derived, nor do they account for weight gain greater than 14.0 lbs.

## Chapter 4

## CLINICAL FACTORS ASSOCIATED WITH WEIGHT GAIN

The question of how much weight a woman should gain in pregnancy is not just an academic matter. There have been a number of studies clearly linking maternal weight gain with various clinical parameters of maternal and fetal health.

### 4.1 BIRTHWEIGHT

The birthweight of the infant has been closely linked to weight gain. Thomson and Billewicz(40), in their 1957 study of 4200 primiparas in Aberdeen Scotland, noted that the incidence of prematurity (birthweight <2500 gr.) fell with increasing maternal weight gain. With very large gains, however, they noted an increase in the numbers of prematures. Prematurity associated with low weight gain seemed to be due to actual poor fetal growth, and not to recognized diseases of pregnancy. Low birthweights of infants of mothers with excessive weight gain appeared to be secondary to early termination of pregnancy due to preeclampsia.

Humphreys(14) in the study mentioned earlier, found a "...small but significant..." relationship between maternal weight gain during pregnancy and fetal birthweight. This held true both for weight gain in pounds, and in percent of prepregnant weight.

Hytten and Leitch(15) also looked at the incidence of prematurity. Their findings were quite similar to those of Thomson and Billewicz. They found the incidence of prematurity to be highest when the mother put on the least weight. It was least common in the middle weight distributions, and increased again in women gaining excessive amounts (again thought secondary to preeclampsia).

Eastman and Jackson(8), at the Johns Hopkins Hospital, again found birthweight very closely tied to maternal weight gain. They used linear regression to show an almost straight line correlation between birthweight and pregnancy weight gains over ten pounds. They also found that the role of weight gain in influencing birthweight seemed more important than a number of other factors. Weight of the newborn increased with maternal gain regardless of the prepregnancy weight of the mother, for example. Also, the relation between maternal height and birthweight seemed to function through the medium of weight gain. The same was found to be true for maternal age and parity.

Singer, Westphal and Niswander(35), used data from approximately 10,000 pregnancies studied in the Collaborative Study of Cerebral Palsy. They divided subjects into four maternal weight gain categories, and examined birthweight and a number of other factors in relation to maternal gain. They, too, found a positive correlation between gestational weight gain and birthweight. In addition, the incidence of prematurity decreased the higher the weight gain, even when controlling for length of getation. The prematurity rate for all 34 to 36 week gestations was 26.1 per 100. In infants of women who gained greater than 26 lbs., how-

ever, the incidence of prematurity, for the same length of gestation, was only 11.1 per 100.

Love and Kinch(21) looked at surviving normal single births of uncomplicated pregnancies in London, Ontario from 1960 to 1962. They found that birthweight increased with maternal gain. They also noted (in contradiction to Eastman and Jackson's study) that there was indeed a significant correlation between prepregnant weight and birth weight. The role of maternal ht was examined, but it did not correlate with birth weight when they controlled for weight gain.

In their study on the clinical significance of total weight gain in pregnancy Nyirjesy, Longeran and Kane(30) found a "high correlation" between maternal weight gain and mean birthweight of the infant. With gains greater than 10 lbs. (4.5 kg), mean birthweight increased with increasing pregnancy weight gain. They noted, however that the incidence of "average-sized" infants (3001 to 3500 gr.) did not vary. There was instead a lower incidence of <u>low</u> birthweights with increasing weight gain, and an increase in the number of babies over 4000 grams. (See figure #2.)

Bergner and Susser(2), in a paper published in 1970, examined data from a number of studies of maternal nutrition during famine times. Although they do not give actual weight gain data, they do note that mean birth weights decrease under famine conditions, like those in Holland 1944-45. They found that lowest mean birthweights in Holland at that time were those in which the exposure to famine was during the last half of pregnancy. Birthweight seemed to rise right after the famine was

over, and from this, they concluded that the the restoration of an adequate diet, even late in the pregnancy, may overcome the effect of an earlier nutritional deficit. If one can assume that weight gain is dependent on nutritional intake, then it is likely that weight gain during the famine was low, as were the birthweights. Once food became more available, weight gain probably improved dramatically, and the birthweight improved correspondingly.

All of the studies seem in fairly uniform agreement as to the strong correlation between weight gain in pregnancy and the birthweight of the infant. Although one can not assume that weight gain actually influences birthweight, at least it seems to be a useful factor to consider when trying to assess the weight, and indeed the viability of the newborn.

### 4.2 PERINATAL MORTALITY

Perinatal mortality also seems to be related to weight gain in pregnancy. Thomson and Billewicz(40) found that the perinatal mortality rate was lowest with a gain of twelve to sixteen pounds from twenty to thirty-six weeks of pregnancy. The incidence for such a gain was 11.9 per 100 births, whereas that for the next weight group, (16-20 lbs. from 20 to 36 weeks), was 27.8 per 1000--more than double. The rate for the low maternal weight gain group was even higher, at 36 per 1000 births. They note that the low rate with the moderate gain probably reflects the fact that the "...foetus has the best chance of escaping the hazards of preeclampsia and prematurity."(p. 245) They did find, however, that perinatal mortality seened to follow the trend of prematurity more than that of preeclampsia.

Hytten and Leitch(15) also found that a weight gain in the moderate range was associated with the lowest incidence of perinatal mortality. Extremes of weight gain were associated with a higher incidence of death. This study, too, seemed to show that perinatal mortality and prematurity follow the same trend with respect to weight gain.

Nyirjesy(30), in his study of 12,568 primips in twenty-two naval hospitals across the U.S., found an overall incidence of 7.40 perinatal deaths per 1000 births. This study, however, showed significant variation in the incidence of perinatal mortality among various weight gain groups.

The Collaborative Perinatal Study of the National Institute of Neurological Diseases amd Stroke(29), which looked at numerous parameters in over 50,000 pregnancies in fifteen hospitals in the U.S., found a clear association between maternal weight gain and perinatal mortality. They noted a downward trend in perinatal death rate with increasing weight gain in whites and blacks. Among whites they note a minimum mortality rate with a gain of 20 to 29 lbs, and an increase above this gain. In black patients, the increase with weight gains over 29 lbs. was not noted.

In Richard Naeye's(29) article reviewing the findings of the above mentioned Collaborative Perinatal Study, he discusses clinical material relating to all fetal and neonatal deaths in the study. He divides women into weight gain groups by using 27 lbs. as optimal gain for term pregnancies, this figure being that used by the National Academy of Sciences. Optimal cumulative weight gain valuies were calculated for each

week of pregnancy and then each pregnancy weight gain was expressed in percent of the optimum value for length of gestation. He found then that the lowest perinatal mortality rates corresponded to a weight gain within 80 to 120% of the "optimum" value, at least for "desireable", or "less than desireable" prepregnancy weights (as defined by the Metropolitan Life Insurance weight for height table). With "heavier" mothers, the mortality rate was actually lower with a lower than average weight gain.

## 4.3 OTHER FETAL AND INFANT PARAMETERS

Birth weight and perinatal mortality are not the only aspects of infant well being which have been investigated. Naeye(27) was involved in another study, for example, in which he examined material from 467 autopsies on stillborn and newborn infants in Babies Hospital in New York City. Two groups of women, those who gained very little, and those with very high weight gains, were compared in terms of fetal outcome. Gestational weight gain was found to affect fetal body size, organ growth, and even cellular growth. Naeye notes, however, that the weight gain effect was much more important after thirty-three weeks gestation.

Barbara Luke, et.al.(22),in an investigation of 637 pregnant women at the Sloane Hospital for Women in New York, found that weight gain correlated not only with birthweight, but also newborn length and head circumference. Both length and head circumference showed steady increase with increasing maternal weight gain. The increase in length, however, was not based on a weight/height ratio.

Singer's group(35), in their study using data from the Collaborative Study of Cerebral Palsy, found that maternal weight increase had a significant correlation with characteristics of the infant up to a year after delivery. Growth and "performance" in the first year of life were more advanced with increasing weight gain. The incidence of abnormals (defined arbitrarily for each variable as the lowest 10% of the entire population) fell in increasing weight gain. This was statistically significant for mental performance, motor ability, height and weight. In addition, the frequency of male births also increased with increasing gestational weight gain. With a fifteen pound gain, there was a 47.6% male birth incidence, whereas with gains over ssixteen pounds, the number of males born increased to 53.12%.

## 4.4 PREECLAMPSIA

Preeclampsia is a maternal complication which has been associated with maternal weight gain in a number of studies. Thomson and Billewicz(40), divided their patients into three groups- preeclamptics with albuminuria, cases with other hypertensive complications, and cases without hypertensive complications. Rate of weight gain in preeclamptics was greater at all stages of pregnancy than in normotensives. Also, in preeclamptics the rate of gain increased as the pregnancy progressed, whereas in normotensives there was a maximum rate of gain from 20 to 30 weeks.

The study by Nyirjesy, et.al.(30), looked at the relationship between maternal weight gain and preeclampsia. They divided women into eleven

different weight groups, and they found that the incidence of preeclampsia increased with increasing weight gain in women who had gained over 16 lbs. In women who gained over 25 lbs., the higher incidence was statistically significant. The incidence in the 36 to 40 lbs. gain group was 12.8%, for example, whereas the overall incidence was 6.22%, and in women gaining 21 to 25 lbs., it was only 4.9%.

Hytten and Leitch(15) also found that the incidence of preeclampsia increases with weight gain. With high weight gains the incidence seemed to actually accelerate. (Figure #3)

The book "Maternal Nutrition and the Course of Pregnancy"(23) discusses studies which have looked at weight gain and preeclampsia. The first, by Tomkins, et.al., actually found that underweight women who fail to gain "normally" during pregnancy tend to have more severe cases of preeclampsia. The authors do not, however, discuss the incidence of preeclampsia in different weight groups. The other study mentioned is that of Eastman and Jackson at Johns Hopkins (previously unpublished data). Of 1933 women who gained "excessively" (over 30 lbs.), 172 (8.9%) had preeclampsia. In the group gaining less than 30 lbs., 5.9% (639 out of 10,789) were preeclamaptic. These data "...appear to discount the importance of large gains in weight during pregnancy..."(p.173), according to this publication. They conclude that it is the <u>pattern</u> of gain and not the actual amount which is more significant.

## 4.5 LABOR AND DELIVERY

Duration of labor has been investigated with respect to gestational weight gain in a couple studies. Humphreys(14) found that although his data at first appeared to support a link between weight gain and duration of labor, it was actually the effect of parity and not weight gain which was being observed. When primiparas and multiparas were considered separately, no significant correlation was seen. Nyirjesy(30), on the other hand, found that the duration of first and second stage of labor increased with increasing weight gain, in a patient population consisting only of primparous women with 40 week gestations.

Nyirjesy noted that the frequency of mid-forceps delivery was greater in patients who gained over thirty-five pounds. He also looked at post-partum complications, but found no correlation between weight gain and problems after delivery.

## Chapter 5

## THE QUESTION OF OPTIMAL OR IDEAL GAIN

Given, then that weight gain in pregnancy is important with respect to the clinical factors which have been discussed, it would be quite useful if one could determine an "ideal" weight gain. Indeed, a number of the previously mentioned studies attempt to establish an optimal figure.

Thomson and Billeweicz(40), for example, state that"...moderate rates of gain are clearly associated with the most favorable experience."(p.246). They recommend gains in the range of .75 to 1.25 lbs. per week, at least during the second half of pregnancy. Such gains were shown to have the best clinical results. They do point out, however, that it does not follow simply that avoidance of high or low gain by dietary regulation will lead to the same favorable outcome seen in women who gain the "correct" amount when "...left to their own devices" (p. 246).

Eastman and Jackson(8) are fairly specific in their suggestions with respect to weight gain. If prepregnant weight is less than 120 lbs., one should eat to appetite until mid-pregnancy. If, at that time, gain is less than 10 lbs., a change in diet should be urged. They note that the overall goal should be to keep weight gain as close as possible to the average, which in their study was 22.1 lbs. total weight gained in white women, 20.5 lbs. in black women.

Singer, et.al.(35), view optimal gain in light of incidence of prematurity. They do not give any figures as to exact weight gain, but note that "...abandonment of weight control practices during pregnancy may reduce the incidence of prematurity."(p.421) They are quick to note, however, that further study would be necessary to discern the relative risk of problems associated with high weight gain, such as toxemia, perinatal mortality and cesearian sections.

Ideal weight gain was described by Nyirjesy, et. al.(35), as the amount associated with the lowest frequency of undesireable or pathologic events. By their study, this would be a gain of 16 to 20 lbs., "...most likely 18 lbs." They also point out, however, that the average total gain in their study was 21.9 lbs, and that there was a standard deviation of 8.3 lbs.--i.e., only gains less 5.3 lbs., or greater than 38.5 lbs,. could be considered statistically abnormal.

Hytten and Leitch(15) view ideal gain as that associated with the lowest incidence of "abnormalities." In considering preeclampsia, perinatal mortality and prematurity, they found that a gain of slightly less than 20 lbs. in the second half of pregnancy correlated with the best reproductive performance. They note that this is compatible with Thomson and Billewicz' earlier work.

Naeye(29), in his study observing women with respect to prepregnant weight for height, concludes that desireable weight gain in pregnancy varies depending on prepregnant weight for height. Desireable gain was that associated with the lowest incidence of perinatal mortality. When the mother was normal or below normal prepregnancy weight for height,

the lowest perinatal mortality was seen with gains of 80 to 120% of an optimal gain (explained earlier). Very thin mothers had the lowest perinatal mortality with a gain of about 30 lbs. Overweight women, on the other hand, did best with about 24 to 54% of the "optimal" gain, about 15 or 16 lbs.

## Chapter 6

## FACTORS AFFECTING WEIGHT GAIN

Given the importance of weight gain in pregnancy, it is of interest to examine factors which influence maternal gain. This study will look particularly at the role of smoking and of prepregnant weight for height, but there are other factors which have been shown to influence weight gain.

### 6.1 LENGTH OF GESTATION

Length of gestation has been quite clearly linked to maternal weight gain. Singer, et.al.(35), found that increasing weight gain was significantly related to increasing length of gestation. Love and Kinch(21) also found statistically significant correlation between length of gestation and maternal weight gain.

### 6.2 PARITY

Parity has also been linked to weight gain. Humphreys(14) found a 2.7 lbs. higher mean gain in primiparous women than in multips, which was statistically significant. Hytten and Leitch(15) note that examination of records reveals that multips gain about a kilogram less than primips. They state, however, that it is unclear whether this is due to parity itself or age of the mother (or both). It appears that there are no good studies to distinguish the two.

## 6.3 AGE

Age as a factor in weight gain was examined by Humphreys(14). Younger women tended to gain more weight- even when divided according to parity. Humphrey's paper notes that his results were in agreement with a number of earlier studies. Thomson and Billewicz(40) did not find much variation in weight gain with respect to age, but did state that older women gained slightly less than those who are young.

## 6.4 NUTRITION

Caloric intake during pregnancy should quite obviously be an important factor in determining weight. Interestingly, however, few good studies have investigated the role of nutrition in maternal weight gain. One of the first to study caloric intake in pregnancy was the German physician Prochownik. In the late 1800's, he placed women on fluid- and calorie-restricted diets, hoping to control weight gain and thereby the size of the fetus in women with contracted pelves. He also tried to use diet to limit weight gain in obese women who had had previous difficult labours.(15)

In reviewing studies of weight gain in pregnancy, Hytten and Leitch(15) found that American women tended to gain less than European women in more recent studies. This they attribute directly to caloric intake, in that American women tend to diet more, both the preserve their figures, and to avoid cardiovascular disease.

There are a couple studies looking at weight gain and caloric intake in situations where caloric intake is rather severely restricted-- i.e. famine. In post-WWII (1945) Germany, for example, pregnant women were "...below weights usual in more usual times."((2)p.956) Birth weights were also lower, as they were in post-war Holland, and during the siege of Leningrad--presumably, low birthweight was directly related to poor caloric intake and weight gain. Indeed, Bergner and Susser propose that the influence of caloric intake on birth weight is through the medium of weight gain.

Raman(33), an Indian researcher, notes that in India, where malnutrition is a huge problem, poor women gain an average of only 6.5 kilograms during pregnancy. Raman also notes that there is a strong positive correlation between maternal health (which is quite linked to nutritional status) and maternal weight gain.

In a study by Virginia Beal(1) at the University of Colorado in Denver, data were analyzed for ninety-five pregnancies in fifty-four women as part of a longitudinal study of the growth and development of their children. The diet of these women was monitored throughtout pregnancy, and the results showed a positive correlation of caloric intake to weight gain. The correlation was noted to be statistically significant, however, only for the second trimester.

A.M. Thomson(39) monitored diets of 489 pregnant women in Aberdeen in 1950 to 1953. The diets of the women were not restricted. Caloric intake increased with rising rate of gain. The correlation coefficient between weight gain and caloric intake was 0.3. Thomson notes that this

is as large a coefficient as one might expect, given that certainly not all added calories will go to increased gain, and that weight gain in pregnancy involves other components, such as increased storage of water.

## 6.5 NON-NUTRITIONAL INTRINSIC FACTORS

Richard Naeye's(29) paper on weight gain and the outcome of pregnancy mentions a number of non-nutritional factors which influence pregnancy weight gain. These include extracellular fluid volume, including edema and the volume of amniotic fluid, and abnormal fetal growth secondary to chromosomal and non-chromosomal congenital anomalies, congenital viral infections, decreased uteroplacental blood frow, and maternal diabetes. Although Naeye gives no references or data, it is quite clear that each of these problems can directly alter weight gain.

## 6.6 PREGRAVID WEIGHT/BODY SIZE

The question of whether the size of a woman before pregnancy influences how much she will gain has been studies by a number of people. Interestingly, conclusions have been far from uniform, one reason why this question is a major emphasis of the present study.

Hytten and Leitch(15), in their book "The Physiology of Human Pregnancy," note that early studies, done by German obstetricians, found that heavier women put on more weight than lighter women. More recent studies, however, seem to show quite the opposite-- that lighter women put on more weight. These authors suggest that the recent studies, most of which are American, may reflect the trend toward slimming, allowing

thin women to gain more weight than obese ones. Hytten and Leitch also note, however, that high weight gains in heavier women may, in an unselected series, be at least partially due to preeclampsia, which has been associated with both high weight gain and obesity.

Poidevin(32), an Australian researcher, published a study in 1960 dealing with prepregnant body weight as related to weight gain. He looked at 228 patients which were at the high and low ends of a larger group studied at a hospital in Australia. He found that absolute and relative gains during pregnancy were highest in the lowest initial weight group. Heavier women showed a smaller absolute gain.

Humphreys(14) examined the relationship between pregravid weight and weight gain in his study of 1000 Welsh women in the 1940's. He found no significant relationship at all, but also looked at weight gain as a percentage of prepregnant maternal weight. He found a slight, but statistically significant inverse relationship between percentage gain and prepregnant weight.

A Canadian study published in 1964 by Love and Kinch(21) showed similar results. The heavier the woman prior to pregnancy, the less she gained. There was a significant negative correlation between weight gain and preconception weight.

Eastman and Jackson(8), on the other hand, did not show such a strong correlation between weight of the mother before pregnancy and her weight gain. In fact, women below 160 lbs. showed no correlation at all, and mean gains for various weight groups were nearly identicle, ranging only

from 22.0 to 22.4 lbs. in the 160 to 179 lbs. range, and 16.3 lbs. in women greater than 180 lbs.

Nyirjesy(30) found no significant correlation at all between non-pregnant weight and weight gain. In women who were under 120 lbs. before pregnancy, weight gain was 21.95 lbs. In women above 140 lbs., avcerage gain was 21.77 lbs., not statistically different.

Nyirjesy also looked at height of the mother, to see if this parameter of maternal size might be correlated with weight gain. Again, no significant correlation could be found. Women 64 inches tall or less gained an average of 21.5 lbs, and women 66 inches tall or more gained 22.4 lbs, again not statistically significant.

There have actually been very few studies where the mother's prepregnant weight for height was investigated with respect to gestational gain. Thomson and Billewicz(40) looked at weight gain from the 20th to 30th weeks of gestation in light of an "obesity index." Prepregnant weights of the women in the study were not known, so they determined this "index" by relating the weight of a patient at twenty weeks to the median weight for all women of the same height. Average gains during the ten week period actually did not vary much in relation to the "obesity index," although underweight women gained at slightly lower rates.

The authors pointed out, however, that since obesity was being assessed at twenty weeks, women may have put on a relatively large amount of weight during the first half of pregnancy. Women classified as "moderately overweight" in their study may have been those who had been

gaining at a higher rate all along. Interestingly, women who were extremely heavy at twenty weeks did not gain more than the average. They were apparently heavy to start with, not high rate weight-gainers.

The only other significant study of weight for height and pregnancy weight increase was that published by Richard Naeye(29) in 1979. He used data of the Collaborative Perinatal Project, mentioned earlier, to examine the question of optimal weight gain in pregnancy. Naeye used the New York Metropolitan Life Insurance Company tables for standard desireable weights for height(6). Each woman's prepregnant weight (obtained by interview) was calculated in percent of the Life Insurance table optimum values, and the women were divided into groups of overweight (>135%), average (90 to 135%), and underweight (<90%). Naeye defined optimal gain as that where perinatal mortality was lowest, and as mentioned earlier, he found that the "underweight" women gained about thirty pounds optimally, whereas the figure for "overweight" women was only fifteen pounds. The "average" group had an optimal gain of around twenty pounds. He does not, however, discuss whether the women in these different groups actually do gain differnently, based on their body size.

## 6.7 CIGARETTE SMOKING

Smoking has more recently been investigated as a factor important in prenatal health, and among the effects it may have on pregnancy is a role in weight gain. Davies, et.al.(5), of Wales, published results of a study in 1976, in which they examined 1159 mother and infant pairs to

learn the role of smoking in weight gain and fetal growth. They divided the mothers into three groups-- non-smokers, light to moderate, and heavy smokers. They found quite clearly that non-smokers gained significantly more weight than heavy smokers, and moderate smokers were intermediate between the two.

Rush(34), in 1974, also investigated the role of smoking in weight gain, and he, too, found that smoking women gained less than non-smokers. Women who reported smoking at initial exam had a significantly lower subsequent mean gain--0.73 lbs. per week, as opposed to 0.90 lbs. per week for non-smokers. Smoking women also showed a decreasing rate of weekly gain with increasing number of cigarettes smoked (0.17 lbs. less per week gained per cigarette). Women in the study who stopped smoking before delivery had higher weight gain than those who continued.

Meyer(24), in a very large study published in 1977, looked at 31,788 births in Ontario from 1960 to 1961. The goal of this project was to determine if the prematurity associated with smoking is mediated by an effect on appetite, eating and weight gain. The results may be seen in figure #4. When distributions of maternal weight gain in term pregnancies were compared for smoking and non-smoking women, maternal smoking did not affect the distributions. Among private patients, median weight gains were 22.55 and 22.59 lbs. for smoking and non-smoking patients respectively. The figures for public patients were 22.60 lbs. for smokers and 22.59 lbs. for non-smokers.

A recent study done in Dublin by Murphy, et.al.(26),looked at a small, but carefully selected group of women who delivered at the Coombe

Lying-In Hospital. Of the 47 women included in the study, 27 were non-smokers, and 20 smoked in excess of ten cigarettes per day. The women were compared for weight gain, infant birth weight and average weekly BPD growth. Non-smokers showed a mean weight increase of 10.5 kg, while the figure for smokers was 11.4 kg. The difference between the two was not statistically significant.

Interestingly, Murphy, et. al., did find significant differences in birth weights and weekly biparietal diameter (BPD) growth. This is one of many studies which have shown significant differences between babies of smoking and non-smoking mothers. Meyer's study(24), mentioned above, found a downward shift in birthweight directly related to the number of cigarettes smoked. Evidence of fetal growth retardation was found among babies of women who smoke by Bosley(4), Haworth, et.al.(13), Miller, et.al.(25), Lampe,et.al.(20),and Davies, et.al.(5). Parameters examined in these various studies included birth weight, head circumference, body length, and skin fold thickness. Naeye's study (29) provided some even more alarming results. In offspring of smokers, he found that a small degree of growth retardation persisted to seven years of age-- the children were slightly shorter and had a smaller head circumference.

A number of these studies attempted to explain the mechanism which causes smoking women to have smaller babies. The work by Meyer, mentioned above, specifically examined the question of whether low weight gain in smokers leads to smaller babies. They found, however, that weight gain did not vary with smoking, although birth weight did. The conclusion was that the "nutritional hypothesis" could not account for

the low birthweights of infants born to smokers. In fact, Meyer proposes that any apparent decrease in weight gain in women who smoke is due to decreased fetal weight gain, and not visa versa. Since, according to Hytten and Leitch(15), the fetus at 30 to 40 weeks accounts for about fifty percent of the maternal gain, Meyer notes that it follows that any fetal growth retardation will be reflected in maternal weight gain.

Davies, et.al.(5), did not come to the same conclusions. They attribute their finding of decreased weight gain in smokers to an effect on appetite, resulting in lower food intake, a theory previously proposed by Rush(34). They claim that their data suggest that the major part of the effect of maternal smoking is mediated through maternal weight gain. They even suggest that one might boost birthweight via dietary supplementation in women who can not stop smoking. They do admit, however, that there may also be a direct toxic effect of tobacco smoke, since the difference in birthweights of infants of smokers and non- smokers persists, even when the data is corrected for differences in maternal weight gain. They somehow quantify this to be only a "...very small additional effect on the fetus," however. Interestingly, Davies goes on to mention that there was a nine percent average drop in birthweight during the Dutch famine in 1944-45, which is comparable to the eight percent drop seen in heavy-smoking women in their study. They note that it is most unlikely that the diet of heavy-smoking women is comparable to that of the wartime Dutch.

A number of the other studies which found fetal growth retardation associated with smoking were unable to attribute their results strictly

to decreased weight gain. Naeye(27) found growth retardation independent of maternal nutrition-- differences remained after the infant growth data had been stratified by weight gain and maternal prepregnant weight for height. Haworth, et.al.(13), in assessing dietary intake, found that fetal growth retardation in smokers was not explainable on the basis of food intake. Bosley, et.al.(4), and Luke, et. al.(22), found a difference in fetal growth parametes which remained significant after correction for maternal variables. Luke, similar to Davies, et.al.(5), suggests that increasing maternal pregravid weight and/or weight gain may at least partially counteract the growth- retarding influence of smoking.

If the effect of smoking on the fetus is not mediated by a nutritional/weight gain mechanism, it would appear that a "toxic hypothesis" should explain the growth-retarding effect. Meyer(24) claims that the evidence in the Ontario perinatal study supports a hypothesis related to oxygen supply. The high levels of carboxyhemoglobin in smokers reduces the oxygen availability in fetal circulation, resulting in decreased growth rate. A smaller fetus would also have less oxygen demand. Interestingly, altitude has effects on pregnancy very similar to those of smoking. A lower birthweight is seen as an effect of altitude, attributed to a relative hypoxia. In the same study, there is also mention of acute effects on blood flow by smoking, as well as metabolic effects, via induction of liver and placental enzymes. Haworth, et. al. (13), and Bosley, et. al.(4), also discuss the toxic hypothesis. Bosley states, "...we postulate from our data and from other data already reported, that the growth retarding effect of maternal smoking on the infant is a complex multifactorial one" (p.729).

Because of the fact that the present study uses a population from the Rotunda Hospital, it is of particular interest to mention work done by Hackett(12), in which a group of ninety women in the Rotunda wards on a particular day (6/15/77) were interivewed about their smoking habits. Of the women interviewed, fifty-five (66.1%) had smoked before the start of the start of the current pregnancy, and forty-nine (54.4%) had smoked after the fourth month. Thirty-three (36.6%) had never smoked at all. Four of the women gave up smoking before they became pregnant, and three of these remained non-smokers. Fifteen tried to stop smoking during the pregnancy, and nine of these continued to abstain. Of the ninety women, eighty-seven knew that smoking was hazardous to the health of the baby. Twenty-seven women cut down during the pregnancy (including those who quit), but twelve actually increased.

## Chapter 7

## USE OF THE BODY MASS INDEX

The Body Mass Index (BMI) used in this study is a ratio of weight to height squared. The index is also called Quitelet's index. Quitelet was a pioneer in anthropometric statistics, who examined both "wt./(ht.)2" and "wt./(ht.)3" as anthropometric indices. He was particularly interested in growth and maturation , and he found that the weight divided by the square of the height was more stable with increasing height than either "wt./ht.", or "wt./(ht.)3".(18)

In more recent times, a number of researchers have shown that "wt./(ht.)2" is the most suitable of the weight/height ratios which have been studied. Keys(18) has noted that a good index of adiposity must be highly correlated with weight (or "fatness"), and relatively independent of height.

Billewicz, et. al.(3), examined "wt./ht.", "wt./(ht.)2", and the Ponderal index (the cube root of weight, divided by height). They looked at a group of over 60,000 British civilians, as well as a group of 6000 primagravidae at the Aberdeen Hospital. All three indices correlated well with relative adiposity, based on body density. However, the Ponderal index was negatively correlated with height, and the "wt./ht." ratio was positively correlated with height. "Quitelet's index...conforms most clearly to 'reality' and appears reasonably satisfactory over a

wide range of heights."(p.187) Billewicz' only objection to the index was the difficulty in calculating it, which today is no longer a relative complaint with the availability of the computer.

Khosla and Lowe(19) compared the same three indices in a group of 5000 men from a large electrical firm in Birmingham, England. They found that "wt./ht." and "wt./(ht.)2", (and not the Ponderal index), were well correlated with weight. They also suggested that one can use mean weight and mean height squared from a population in order to be more practical in dealing with a large population. These investigators refer to Quitielet's index as the "...index of choice for epidemiologic purposes." (p.128)

Finally, both Keys(18) and Goldburt(10) compared the body mass index in various population groups. Keys looked at men being followed for a cardiovascular study, which included 7424 individuals in twelve cohorts in five countries. Goldburt looked at Israeli civil servants, who come from a wide variety of birthplaces and ethnic backrounds. Both studies found that the body mass index to be highly correlated with adiposity and uncorrelated with height. Keys also states that the body mass index has an advantage over the "percent average weight" index used by some investigators, in that it is applicable to all populations at all times. The percent average index is usually based on a select population such as that surveyed by the New York Metropolitan Life Insurance Company. It is then likely to be biased by the social status and ethnic backround of the population studied, which in the case of the Metropolitan Life Insurance tables were people who were applying for life insurance.

# PART III

# DESCRIPTION OF THE POPULATION

# Chapter 8

This study uses data which were obtained from pregnant women visiting the Rotunda Hospital in Dublin during 1979 and 1980. Information was recorded at each of up to five antenatal clinic visits, as well as during hospital admissions and postnatal visits. Approximately 400 different variables were recorded for each pregnant woman, including information concerned with maternal medical, gynecologic and previous obstetrical history, social situation, and, of course, various aspects of the present pregnancy. There were 12,994 total subjects seen over the two year period, although not all data was obtained for each woman.

The women ranged in age from 14 to 51 years, with a mean of 27.6 years. The mean height was 158.9 cm, and the median number of pregnancies was two, including the present one. Mean gestational age at the first gestational visit was 15.2 weeks, and mean weight at first visit was 59.6 kg. Mean gestational age at the last visit was 38.9 weeks, and mean weight at last visit was 69.0 kg. Average birth weight was 3390 gr., and median value for duration of pregnancy was 39.4 weeks.

Approximately 25.5% o the women were working during their pregnancy. With regard to socioeconomic group, 5% of the women had husbands who were "professionals", 17.5% "intermediate professionals", 29% "skilled manual", 17.8% "skilled non-manual", 15.4% "semi-skilled", and 12.4% "unskilled". 92.3% were married. Table #1 provides further information concerning the population.

# PART IV

# MATERIALS AND METHODS

## Chapter 9

This study of weight gain during pregnancy was initially complicated by the fact that there were no available pregravid weights for the women in the study. The first recorded weight was at the first gestational visit, which ranged from the second week of pregnancy to term. For this reason, it was decided to do a cross-sectional analysis of the data. This involved computer cross-tabulation of maternal weight at each visit by gestational age. For each week of gestation, a median weight was calculated. These values were then plotted. Fifth and ninety-fifth percentiles were also calculated, and plotted as well. (Note: A polynomial regression was used in all instances to smooth the curves for plotting.) Women included in this analysis were those with singleton live-born babies, without perinatal, neonatal or late abortion deaths. (Perinatal deaths were those occurring between 28 weeks gestation and one week after birth. Neonatal deaths were those occurring less than 4 weeks after birth, and late abortion deaths were those between 20 and 28 weeks.) This was done because of an interest in looking at weight gain in normal pregnancy and because these factors may be associated with gross aberrations in weight gain. The weight range included in the study was 38 to 99 kilograms.

Next we were interested in examining weight gain in women with respect to height, as a means of looking at weight gain in women with dif-

ferent initial body mass conditions. To do this, the body mass index (BMI) was calculated, using the following formula:

$$\text{body mass index} = \frac{\text{(weight in grams)}}{\text{(height in cm.)}2}$$

As noted in the survey of the literature, this anthropometric index has been shown to be quite accurate, and permits analysis of change in body mass having regard to the mother's prepregnant size. BMI was calculated for each week of gestation, and plotted. Again, only women with singleton, liveborn babies, without perinatal, neonatal or late-abortion deaths were included. Weight range was the same as above. Women included had recorded heights from 140 cm to 200 cm.

Once median BMI was calculated for each week of gestation, women were divided into "underweight", "medium", and "overweight" groups. Women considered "underweight" were those whose first clinic visit was at ten to twenty weeks gestation, and who had a BMI more than fifteen percent below the median value for that gestational age. (Table #2 gives cutoffs used for first gestational visit.) Women were considered "medium" if their body mass index was within plus or minus 15% of the median, and "overweight" if it was greater than 115% of the median.

In this part of the study, birthweight was also controlled, in an attempt to define the change in body mass index which is associated with "optimum outcome." "Optimum" here was defined as birthweight between 3001 and 4500 grams. The 3000 gram cutoff was used on the basis of a study be Valerie Dowding(7), in which she found a 17.6% incidence of "suboptimum" birthweights (<3000 gr) in Dublin. Women bearing infants

with severe congenital anomalies were also excluded. Each of the three groups was cross-tabulated separately according to BMI for gestational age, and median BMI was calculated for each group at each week of gestation (between ten and forty-two weeks). The fifteen percent cut-off point was used primarily in order to have a reasonable sample size in each group. However, it did seem to correspond, more or less, with weight for height used, for example, in the New York Life Insurance Company tables(6), and in the Fogarty Table in Britain(16). The curves for all these weight for height groups were plotted together for better comparison.

For the remaining studies, only women in the "medium" BMI group were included. It was thought that by using a more uniform group of subjects one could better note trends and draw conclusions from the data. Within this BMI group, then, women with "optimum" and "suboptimum" outcomes of pregnancy were compared. "Optimum" was defined again as noted above. "Suboptimum" differed only in that birthweight was less than or equal to 3000 grams. Again, median BMI's were calculated, and the results for both groups were plotted together.

Smoking and non-smoking women within the "medium" BMI group were also compared. Women were considered non-smokers if they did not smoke at all during the pregnancy. Smokers were defined as those who were recorded as smoking at least at their first and second gestational visits. In the smoking group, women with babies of alll birthweights were included, in order that the potential problem of growth retardation with smoking in pregnancy might be taken into consideration and possibly re-

flected in the data. Again, median BMI was recorded, and the results plotted.

# PART V

# RESULTS AND DISCUSSION

## Chapter 10

# INCREASE IN MEDIAN WEIGHT DURING GESTATION

In the first analysis, which was concerned with change in weight in kilograms during pregnancy, data from 58,449 gestational visits was used to generate a plot of median weight versus week of gestation, from ten to forty-two weeks. The number of visits per week ranged from 690 at 25 weeks to 3353 at 40 weeks. Table #3 shows both the raw data, and that obtained when the curve was smoothed using a weighted polynomial regression. The curve is seen in figure #5. Fifth and ninety-fifth percentiles are also shown. The raw data show a change in median weight from 57.4 kg at ten weeks to 68.6 kg at forty weeks, an increase of 11.2 kg (24.6 lbs.). The regression curve reveals an overall increase of 12.4 kg from ten weeks (56.1kg) to forty weeks (68.5 kg). Since the regression curve takes all data points into account, it would appear to be more representative of the entire population.

The results are quite compatible with those of major studies done in the past. Humphreys(14) found a gain of 11.7 kg from twelve weeks to term, and Thomson and Billewicz(40) determined gain from conception to term to be 12.5 kg in normotensive women. Hytten and Leitch(15) used data from their own study and others to arrive at a figure of 11.9 kg weight gain from ten to forty weeks. Studies done more recently reveal a somewhat smaller total gain-- 9.95 kg in Nyirjesy's work(30), and 10.1 kg with Eastman and Jackson (8). Nyirjesy notes that dietary re-

striction was used in his study, however. There is no mention of diet in Eastman and Jackson's report, but they did specifically exclude women with diabetes and toxemia from their study, both of which have been associated with higher weight gain in other studies.

The regression curve is a fairly straight line, suggesting that weight gain is uniform throughout pregnancy-- at about 0.4 kg per week. Many other studies have shown that weight gain is <u>not</u> uniform, however, and the curve as it is may reflect wide ranges of height and weight in seen in the population.

## Chapter 11

## INCREASE IN BMI DURING GESTATION

This part of the study included data from 53,796 gestational clinic visits. The median BMI's, as well as fifth and ninety-fifth percentiles at each visit, may be seen in table #4. The graph of the data, after a polynomial regression was used to smooth the curve, may be seen in figure #6. The number of visits for each week of gestation ranged from 523 at 27 weeks to 3666 at 30 weeks. The change in median BMI based on the raw data (before regression) from ten to forty weeks is 0.44. The regression curve shows an increase of 0.47, from 2.19 at ten weeks to 2.66 at forty weeks. The median height in the original population is 158.9 cm. For a woman of this height, a change of 0.47 in BMI would be a weight gain of 11.87 kg (26.1 lbs.).

This curve appears to be a fairly straight line, similar to that of the change in weight versus gestational age. The change in BMI for each of three ten week periods from ten to forty weeks is fairly uniform. There is an increase of 0.16 in BMI from ten to twenty and twenty to thirty weeks, and 0.15 from thirty to forty weeks. The average change per week from ten to forty weeks is 0.016. This corresponds to 0.40 kg per week for a woman of median height (158.9cm).

Although there are no previous studies which examine the change in this particular anthropometric index during pregnancy, the data do cor-

relate with earlier weight gain studies. The figure given for weight gain in a woman of median height is quite compatible with data in a number of the studies mentioned in the literature survey of this paper. Given the large size of the population studied (53,796 visits representing over 10,000 women), the curve derived should be a very valid representation of change in body mass in Irish women with singleton liveborn babies. As noted earlier, the index being used (also known as Quitelet's index) has been shown to be satisfactory for assessing body mass (11,18,19), and does not appear to be biased by the height of the subjects.

The fifth and ninety-fifth percentile curves follow the median curve with a fairly parallel course, indicating a fairly uniform trend in the population. The ninety-fifth percentile changes 0.45 from ten to forty weeks, and the fifth percentile moves up 0.44 during the same period. The fact that these percentiles do not show the same change as the curve for median value may indicate something about the range of weight gain in the population. For example, a number of very poor weight gaining patients might slightly push down the percentiles without affecting the median.

## Chapter 12

## COMPARISON OF DIFFERENT WEIGHT GROUPS

In this analysis, data was collected to plot curves of change in body mass index for the three weight groups--"medium weights", "underweights", and "overweights", based on BMI at the first gestational visit, as described previously. The three curves of gestational age versus BMI may be seen in figure #7.

The medium-weight group was the largest, providing information from 23,991 gestational visits representing approximately 5000 women. The change in BMI from ten to forty weeks as calcultaed from the data, following use of the polynomial regression, is 0.45. Median indices for each week of gestation, as well as the figures obtained using the weighted polynomial regression may be seen in table #5.

The overweight group was made up of approximately 1200 patients providing data from 5777 gestational visits. The change in BMI from ten weeks to forty weeks is 0.46, almost exactly that of the medium weight group. The figures for BMI at each week of gestation in this group may be seen in table #6.

The group of underweight women was quite small-- 1444 gestational visits represent approximately 300 women. Interestingly, the change in BMI from ten to forty weeks is 0.51, somewhat higher than that found in the medium and overweight groups. Table #7 gives the complete data for the underweight group.

To better compare the change in BMI during the course of pregnancy, table #8 provides figures for various intervals during gestation. In addition to overall change, one can compare data for ten week periods, as well as the figures for the second and third trimesters (13 to 26 weeks, and 26 to 39 weeks.)

In comparing the three data sets, it is clear that the major difference is in the underweight group. The 0.51 increase in BMI from ten to forty weeks is higher than that seen in either of the other two groups, and also higher than the increase for the whole population, which was 0.47, as noted previously. In a woman of mean height for the population (158.9 cm), this would be a weight gain of 12.7 kg (28 lbs.), as compared to 11.2 kg (24.7 lbs) in the medium weight group. and 11.6 kg (25.6 lbs.) in the overweight group. These results are somewhat compatible with those of Richard Naeye(29), at least with respect to the underweight group. He found optimal weight gain in "thin" women to be about 30 lbs. Medium and overweight women gained much less in his study-- 20 and 15 lbs. respectively. Although one can not simply translate body mass information into weight gain, it would appear that the differences noted here are not of the magnitude reported by Naeye.

The results of this study are also not fully compatible with those of Thomson and Billewicz(40). This early study found no difference at all in weight with respect to an "obesity index", which was the ratio of a woman's weight to a median value of all women of the same height. Their study only examnined weight gain from twenty to thirty weeks, however. It is of interest that this is the period of greatest increase in BMI in

all groups in the present study, and that the rate of change at this time is nearly the same in all the groups.

The present project differs from both of the above in that birthweight has been taken into account. The goal here was to find a change in BMI which was associated with normal pregnancy and optimal outcome. Naeye's study was also oriented toward optimum outcome, but was based on mortality rather than birthweight.

The figures presented for the second and third trimesters are consistent with earlier studies which have shown rate of weight gain to be greatest during the second trimester. The increase in BMI from 13 to 26 weeks was 0.23 in the medium weight group, and 0.22 in the over- and underweight groups. From 26 to 39 weeks, the figures are 0.19 for over- and medium weight women, and 0.22 again for the underweight group. Hytten and Leitch(15), in reviewing eight studies that looked at rate of weight gain, found the highest rate of gain to be between 17 and 24 weeks in seven studies. In their own work, too, they found the slope of their weight gain curve to be steepest at or slightly before mid-pregnancy.

The small number of patients in the underweight group bears some consideration. It may be that a cutoff at 15% below the median BMI is so low that women would not be nutritionally fit to support a pregnancy. A woman of average height with a BMI of 1.90 (the underweight cuttoff for twelve weeks gestation) would weigh 48.0 kg (106 lbs.)-- and that is the upper limit. It may be that women weighing much less than this would be amenorrheic. Another factor which most certainly restricts the size of

the underweight group is the limitation on birth weight. Studies by Hytten and Leitch(15), and Eastman and Jackson(8), have shown that low maternal weight is correlated with low birthweight.

The significance of the small population, in term of the results of the present study, is difficult to assess. The small number of women representing each week of gestation would imply that BMI's calculated are likely to be biased depending on who exactly appeared during a particular week. The use of the weighted plolynomial regression should counterbalance some of the bias.

One factor which could not be controlled for, and may influence the overweight group, is preeclampsia. The incidence of preeclamptic toxenmia in the population is not known. Since this problem has been associated with excessive weight gain and obesity (23), inclusion of preeclamptic women could boost the overall increase in BMI.

## Chapter 13

## COMPARISON OF OPTIMUM VERSUS SUBOPTIMUM OUTCOME

The curves of change in BMI for the optimum and suboptimum outcomes are seen in figure #8. The curve for optimum outcome is the same as that of the medium weight group in the foregoing section. The population in the suboptimum group were selected by choosing women who at initial presentation (ten to twenty weeks) were within the same BMI limits as the medium weight group, but who went on to have babies with birthweight less than or equal to 3000 grams. This curve incorporates data from 4643 gestational visits, representing approximately 1000 women. Data for this group are found in table #9.

There are several interesting differences between the two curves. First, they indicate that the women are different in size when they first present at the the clinic. The BMI at ten weeks for the suboptimum group is 2.13, while that of the optimum group is 2.18. For a woman of average height (158.9 cm), this is a difference of 1.3 kg, (2.8 lbs.). This is especially interesting in that the same limits of BMI were used for selection in both groups. These results are consistent with the findings of Kaltreider(17), Eastman and Jackson(8). , and others, who have shown a significant correlation between birth weight and prepregnancy weight.

The group with suboptimal outcome also shows less overall change in BMI. From ten to forty weeks, there is an increase of 0.39, as opposed to 0.45 in the optimum group. The difference of 0.06 would mean a difference in weight gain of 1.5 kg (3.3 lbs.). These findings are quite in agreement with those of Hytten and Leitch(15), Eastman and Jackson(8), Love and Kinch(21), Nyirjesy, et.al.(30), and others. The difference in BMI between the two groups of women can not, of course, represent only the difference in birthweight of the fetus. Although figures are not aviailable for birthweight in each group, the mean for the whole population was 3390 gr. Hytten and Leitch(15), as noted previously, calculated that the fetus accounted for 3300 grams of a 12,500 gram weight gain. It should be remembered that perinatal, neonatal and late abortion deaths, and congential anomalies were not included in the suboptimum group. Babies born to women in this group, whether small for dates or of short gestation, were at least viable at birth.

In examining figure #8, there is an obvious difference in the slopes of the two curves. The difference is most pronounced in the second half of gestation. Indeed, if one examines the change in body mass during selected intervals, as was done in the previous section, the differences in slope are greatest during the final weeks of pregnancy. (See table #10.) The optimum group shows an increase of 0.12 from ten to twenty weeks, as opposed to 0.11 in the suboptimum group. The figures are 0.19 and 0.17 for twenty to thirty weeks. Both groups show a relatively high rate of change at this stage, but the suboptimum group actually continues to fall off from the optimum group. Finally, in the last ten weeks of pregnancy, there is an even larger discrepancy, with a 0.03 difference between the two groups.

The data for the second and third trimesters also emphasize a distinction between the two groups. Although the change from 13 to 26 weeks is equal in both groups (0.23), the rate of change in the third trimester is much greater in the optimum group, which shows a BMI increase of 0.19, as compared with only 0.15 in the group with the suboptimum outcome.

A search of the literature fails to reveal any previous work which has examined the relative rate of weight gain during different stages of gestation in women having low birth weight infants. Thus, in addition to confirming the previously shown association of birthweight with pregravid weight and weight gain, the present study reveals that a relatively low rate of gain in the later stages of gestation is associated with low birthweight. One can not make any statements as to the role of cause or effect here, but it does seem that this information may be of use clinically.

# Chapter 14

## COMPARISON OF SMOKING AND NON-SMOKING WOMEN

The curves for smoking and non-smoking women are seen in figure #9. The curve for smokers is derived from measurements of 10,632 clinic visits, representing about 2,100 women. Approximately 2800 non-smoking subjects were included, providing data for 14,099 visits. The data sets for both groups are found in table #11.

The smoking women are "thinner" than the non-smokers throughout pregnancy. At ten weeks, the median BMI for smokers is 2.13, (2.14 by raw data), while the figure for non-smokers is 2.18 (2.19 by raw data). The difference of 0.05 would represent a 1.3 kg (2.8lbs.) difference in weight between smoking and non-smoking women of average height in the population. This difference is within the medium weight group, such that one might expect it to be larger were all weight groups included in the study. The findings here are quite consistent with those of Goldburt and Medalie(10), who found a lower BMI in smoking men of all age groups. They found a mean BMI of 2.61 in non-smoking men, while the value for those who smoked 11 to 20 cigarettes a day was 2.52. In the study by Luke, et.al.(22), the portion of women smoking in the under weight and normal weight pregravid groups was greater than of non-smokers, who showed a larger percentage in the obese catagories.

There was no real difference between smokers and non-smokers in overall increase in body mass index during pregnancy. Both groups showed an increase of 0.46. The values for various intervals during gestation are included in table #10. These findings are quite compatible with those of the recent (1977) very large study of Meyer in Canada(24). Her work showed that weight gain distributions were not affected by maternal smoking.

The present findings, then, do not support the "nutritional hypothesis" of the effect of smoking on the fetus. There is no evidence here that lack of weight gain can account for the decrease in birthweight, head circumfrence, and other parameters of fetal well-being which are discussed earlier in this paper. Rather, these results lend support to the "toxic hypothesis", which proposes that the effect of smoking is due to the action of chemicals in tobacco smoke on maternal and fetal tissue.

# PART VI

# CONCLUSIONS

Chapter 15

In this study, we have made use of the body mass index to examine weight gain in pregnancy. A cross-sectional analysis was used to examine change in BMI during gestation in a large population. This is the first time this particular index has been implemented in a pregnancy study, and the results indicate that it is a useful and accurate tool.

The curve portraying change in BMI in the total population indicates an overall increase quite in the realm of that found in many recent studies. This curve does not, however, permit full examination of rate of change throughout pregnancy. When the population is divided into groups, however, based on presenting BMI, one can better assess the week by week change in body mass. In this way, the study is able to confirm that rate of gain is highest during mid-pregnancy. Also, the hypothesis that thin women should optimally gain more during pregnancy is supported by this method.

By selecting out a certain weight group as a more "normal" or "average" population (the medium weight group), investigation of other factors relevant to pregnancy is fascilitated. The problem of prematurity is examined here, and the results show three important aspects of weight gain in women giving birth to low birth weight babies. The women are smaller women to begin with- that is, their presenting BMI is below that of the optimum group. Finally, it appears that women with low birth

weight babies fall off in relative rate of weight gain especially in the later stages of gestation, as compared to those with infants of normal weight.

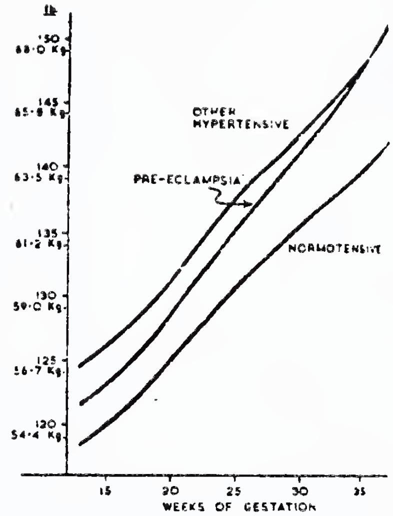
The question of smoking in pregnancy was also examined. Smoking women also presented "thinner", that is with a lower BMI, at their initial visit, and remained proportionally thinner throughout pregnancy. However, there was no apparent difference in change in body mass index between smoking and non-smoking women.

The major difficulty in this study was that posed by the lack of a pregravid weight for the patients. This is hardly unique to pregnancy weight gain studies, and even those which do measure from pre-conception weight usually just inquire as to the previous weight of the patient, hardly an accurate measurement. Since most patients will be presenting to their doctors in the second or third month of pregnancy, and not <u>before</u> they are pregnant, this not an obstacle to the practical relevance of this project.

Other potential problems in this investigation are those common to any large study. We can not be sure of the accuracy of the data recording, and the weights recorded are apt to be influenced by numerous factors, from the scale used to what the patient may have had for lunch. We do not have any information as to the diet of the women, and indeed this would be difficult to monitor in so large a group. It was also not possible to control for preeclampsia when analyzing the data, which may have influenced especially the "overweight" group, as mentioned earlier.

This study could potentially have useful practical implications. Curves of change in BMI might be used to monitor patients throughout pregnancy. With calculators and computers available today, it is an easy figure to calculate, and indeed, doctors could have available charts (nonograms) of BMI over a range of heights and weights. The curve of a woman's increase in BMI might then be plotted during pregnancy, (she might even plot it herself), much as the growth curves of children are plotted on standard age/weight graphs. A deviation from the normal pattern would prompt further investigation, and possibly some type of intervention. In conjunction with other methods of assessing maternal and fetal well-being, the use of the BMI can aid in better monitoring of pregnancy. It is certainly an easily used and inexpensive tool.

Further studies can certainly be done using the BMI in pregnancy. It would be very interesting, for example, to look at change in BMI in other population groups. This would be especially important here in the U.S., since especially in urban areas, patient populations are quite heterogeneous with respect to race, ethnic backround, and consequently, body build. Other potential areas of investigation are those which were examined in the literature survey, such as perinatal mortality, preeclampsia, diabetes, maternal nutrition, age and parity. Use of the body mass index in examining these topics might provide new insight into the management of pregnancy.




Average weight-gain curves in three clinical categories of primigravidae

Figure #1

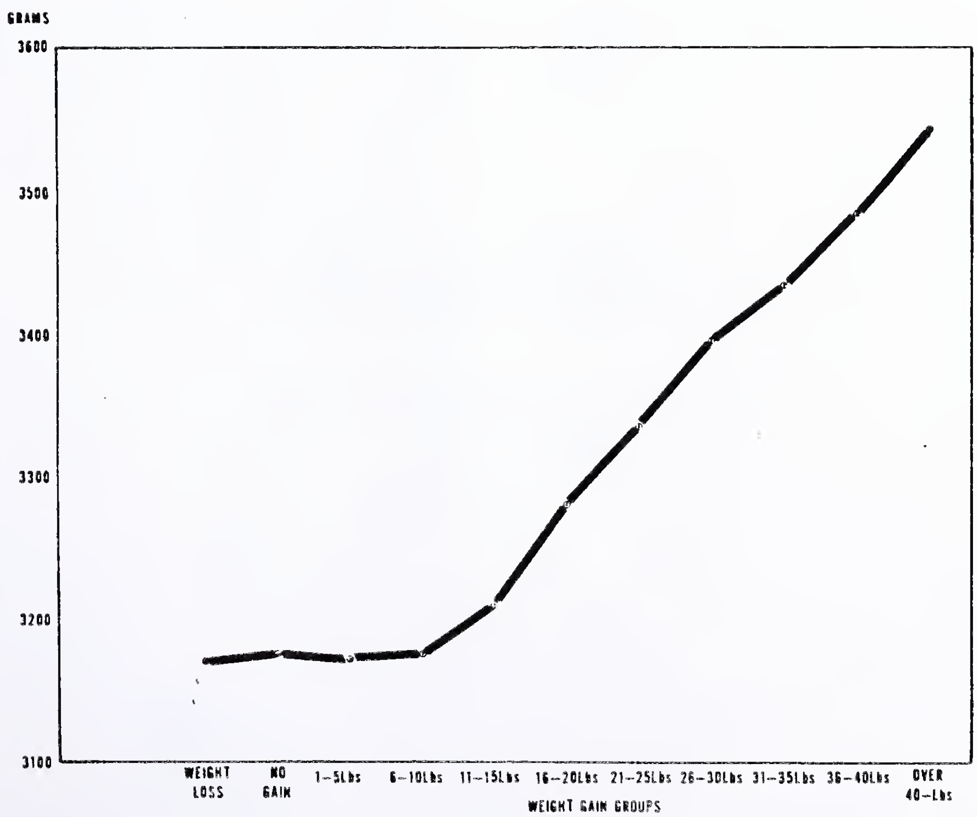



Fig. 2 Mean birth weight related to weight gain, 40-week primipara.

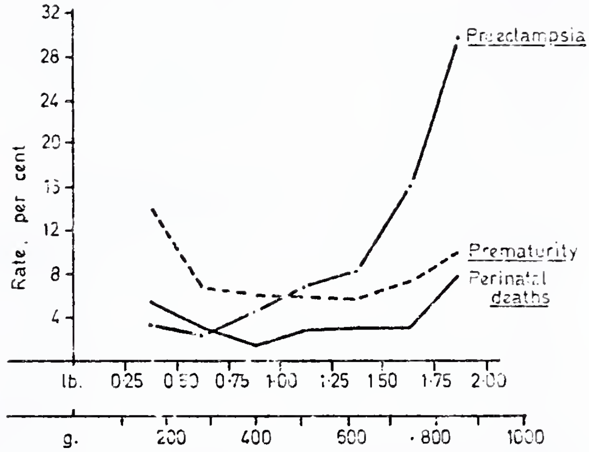



FIGURE 3 Incidence of three major obstetric complications by mean weight gain between 20 weeks and delivery. (Prematurity = birth weight 2500 g or less)

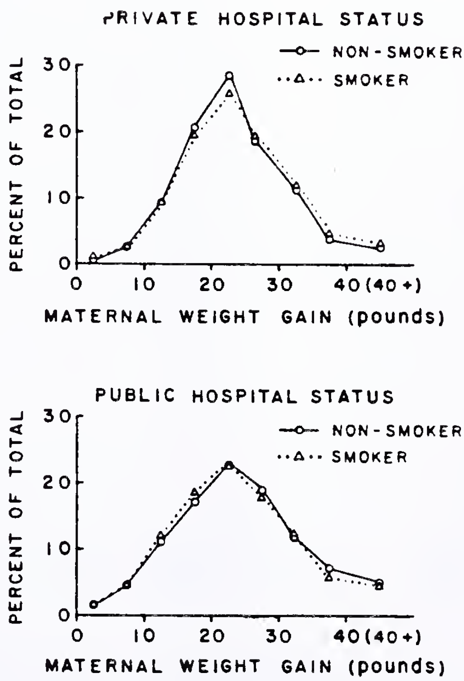



Fig. 4 Percentage distribution of maternal weight gain by maternal smoking. Births of 38+ weeks' gestation. Private hospital status: nonsmokers, N = 12,151; smokers, N = 11,349. Public hospital status: nonsmokers, N = 1,535; smokers, N = 2,955.

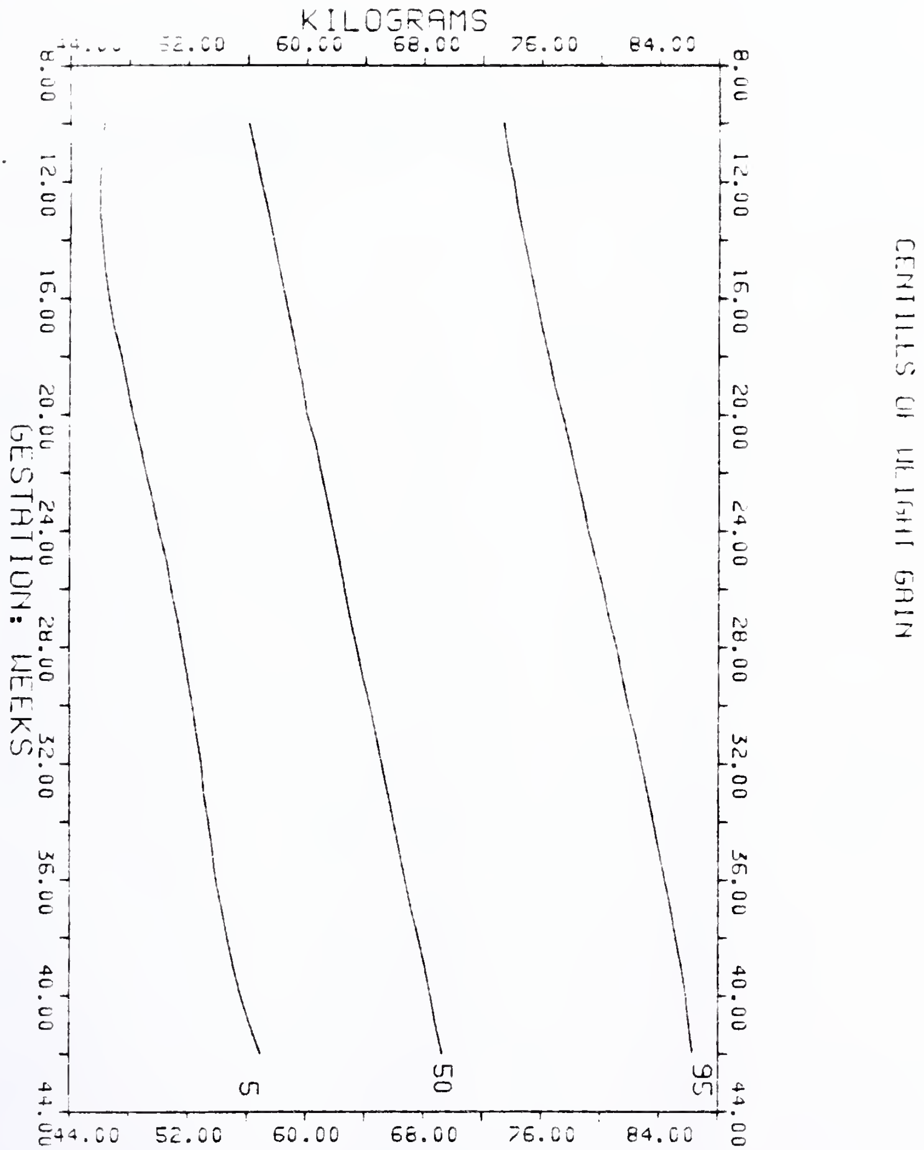
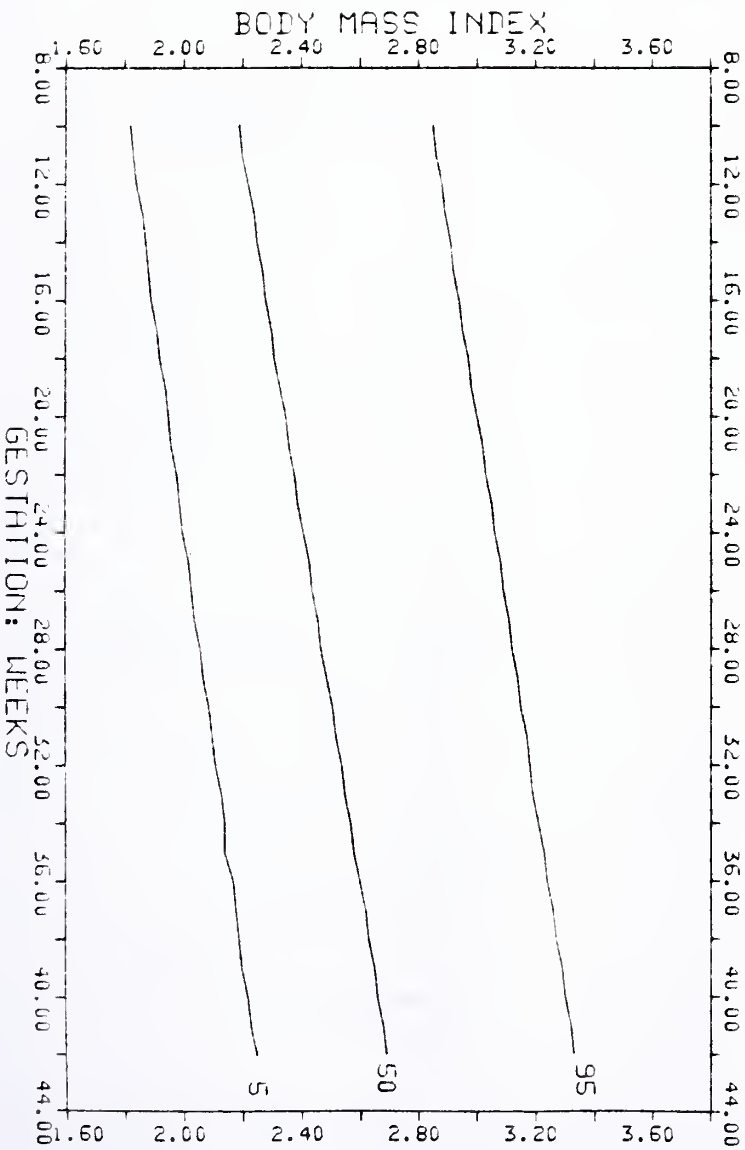

CENTILES OF WEIGHT GAIN
KILOGRAMS
44.00
52.00
60.00
68.00
76.00
84.00
GESTATION: WEEKS
8.00
12.00
16.00
20.00
24.00
28.00
32.00
36.00
40.00
44.00
5
50
95

Figure #5




BMI BY GESTATIONAL AGE - CENTILES

Figure #6

BMI BY GESTATIONAL AGE - MEDIANS

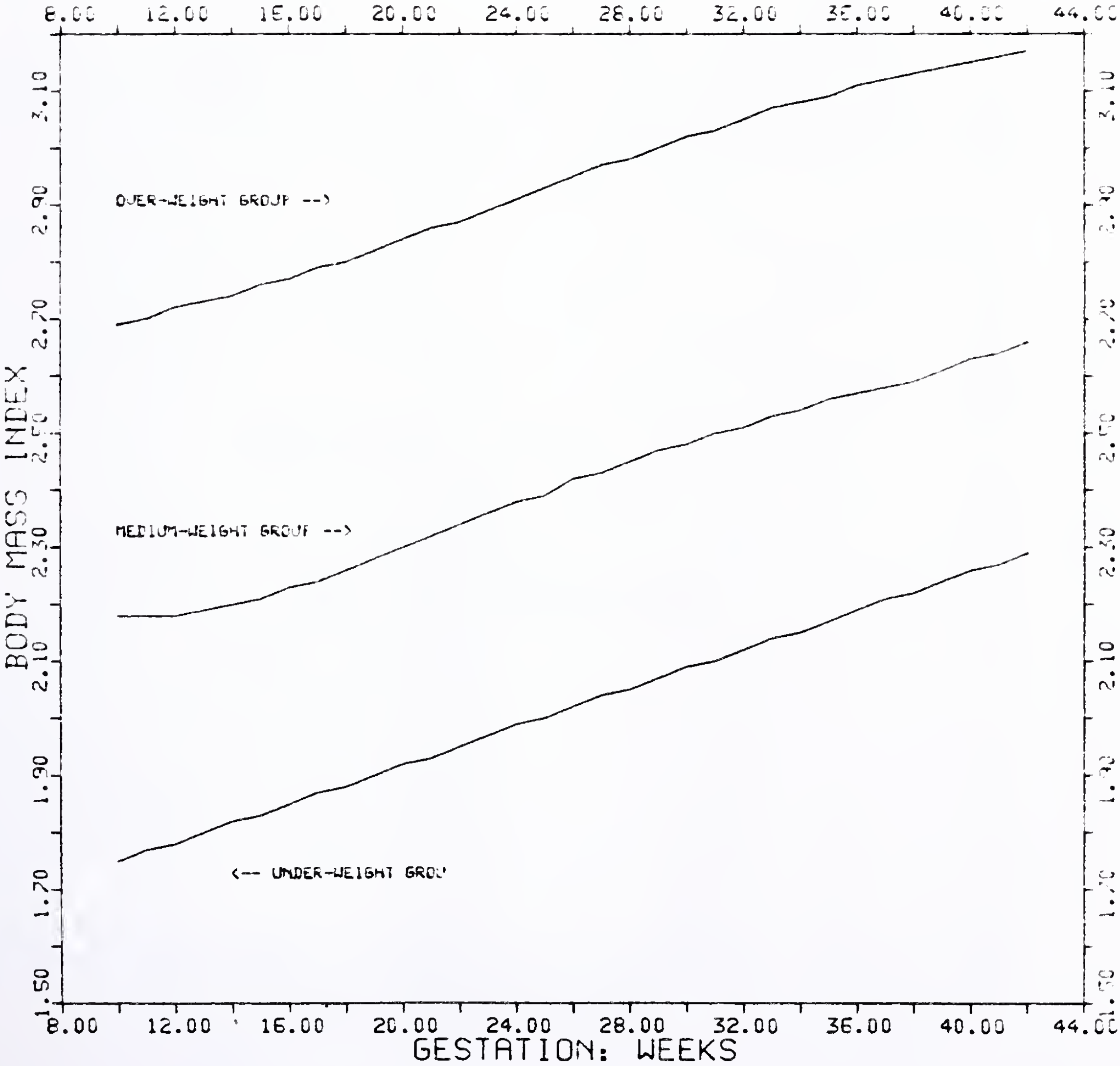



Figure #7

BMI BY GESTATIONAL AGE - MEDIANS

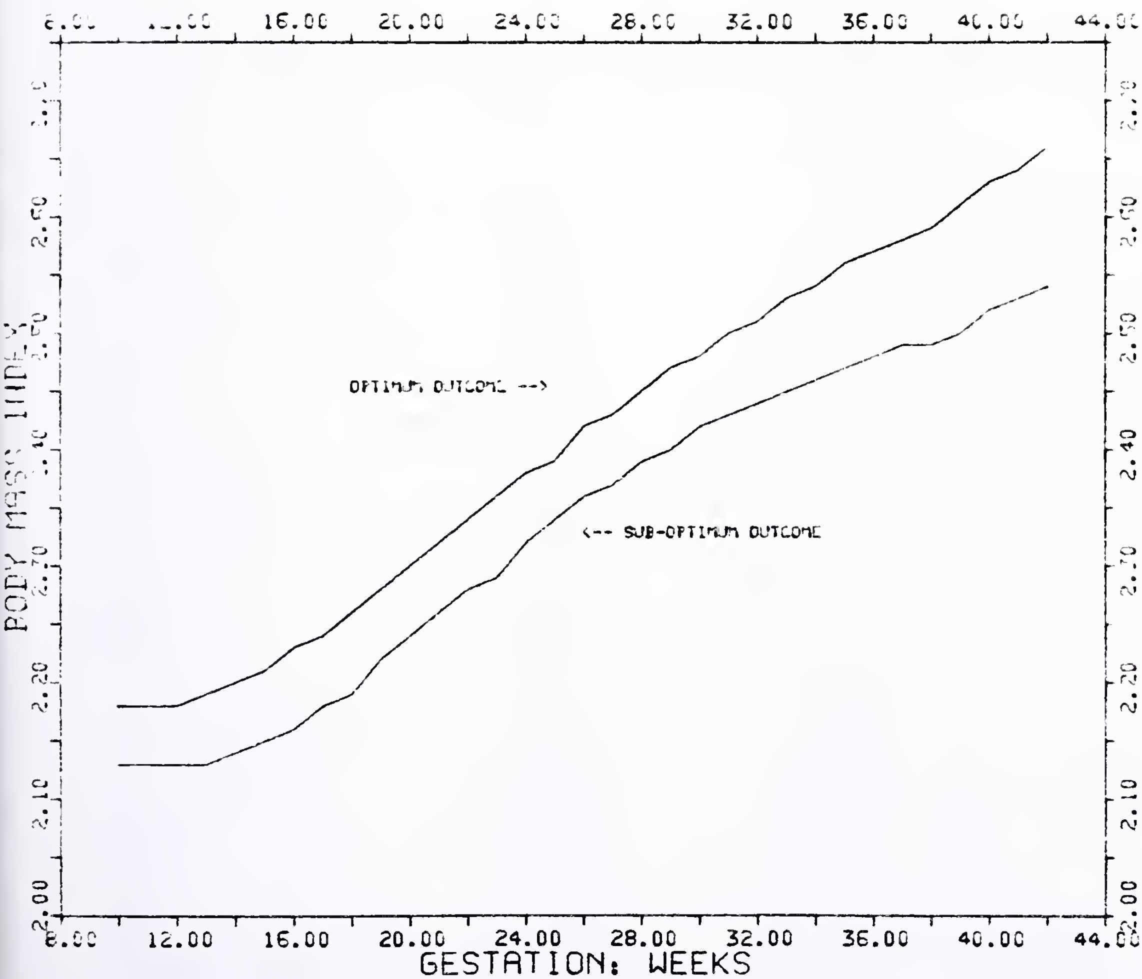



Figure #8

BMI BY GESTATIONAL AGE - MEDIANS

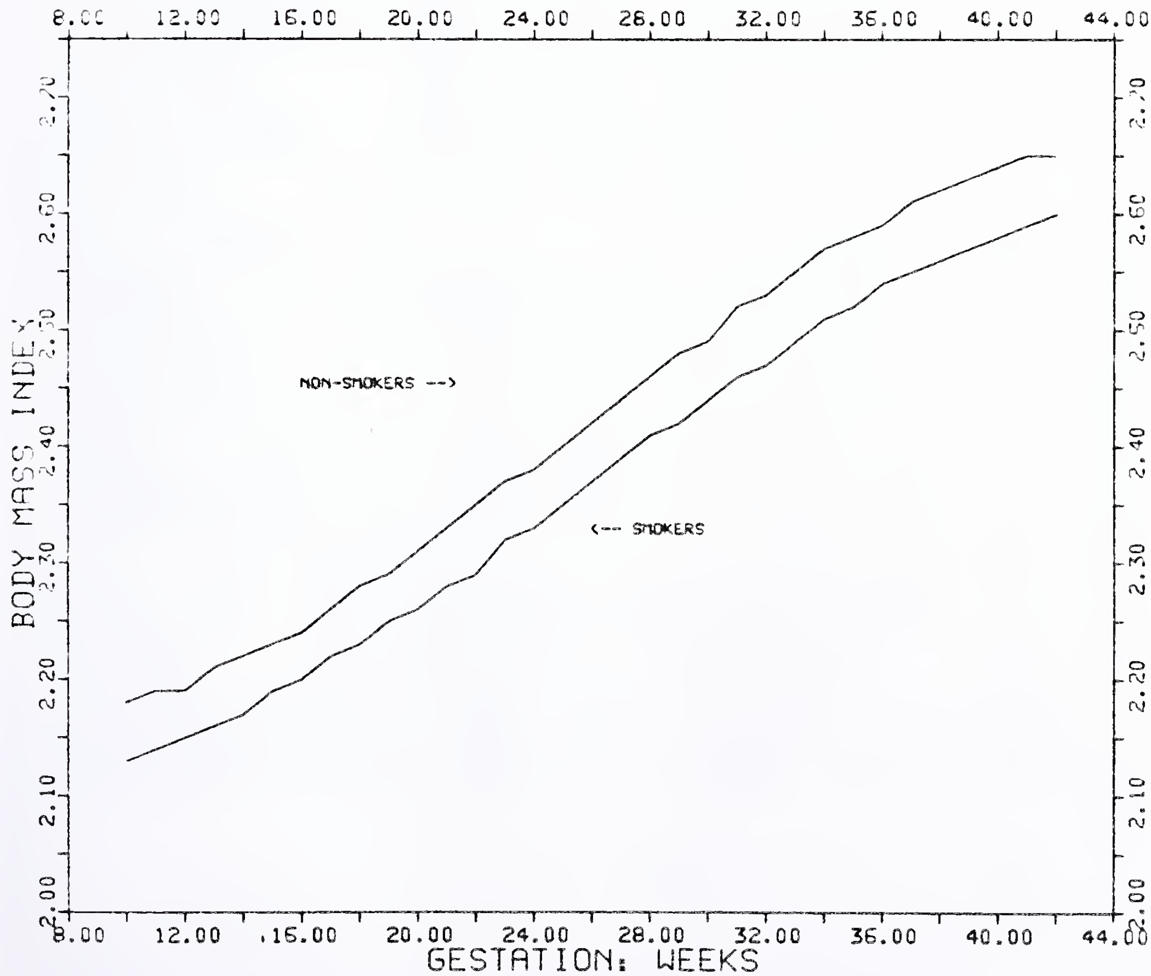



Figure #9

## The Rotunda Study Population Profile

| | Mean | S.D. | Median | Min. | Max. |
|---|---|---|---|---|---|
| Age | 27.64 | 5.77 | 27.0 | 14 | 51 |
| Height(cm) | 158.9 | 5.88 | 159.0 | 131 | 195 |
| Gravida | 2.87 | 1.96 | 2.2 | 1 | 15 |
| Parity | 1.59 | 1.70 | 1.0 | 0 | 14 |
| 1st visit/wks. | 15.21 | 6.14 | 14.0 | 2 | 40 |
| wt 1st visit/kg | 59.6 | 9.3 | 58.0 | 29.0 | 99.0 |
| #cigs 1st visit | 5.91 | 8.8 | 0 | 0 | 80.0 |
| age last visit | 38.86 | 2.65 | 39.0 | 4.0 | 45.0 |
| wt last visit | 69.0 | 9.96 | 68.0 | 21.0 | 99.0 |
| #cigs last visit | 3.36 | 6.4 | 0 | 0 | 60.0 |
| birth weight(gr) | 3390 | 612 | 3400 | 400 | 6000 |

Working Yes- 2985 (25.5%) No- 8729 (74.5%)

Socioeconomic group (#cases/category)

| | | |
|---|---|---|
| 1 professional | 560 | 5.0% |
| 2 Int. professional | 1969 | 17.5% |
| 3 Skilled Non-manual | 2001 | 17.8% |
| 4 Semi-skilled | 1738 | 15.4% |
| 5 Unskilled | 1403 | 12.4% |
| 6 Skilled Manual | 3264 | 29.0% |
| 7 Armed Forces | 313 | 2.8% |
| 8 Student | 22 | 0.2% |

Marital Status

| | | |
|---|---|---|
| 1 married | 11,728 | 92.3% |
| 2 single | 848 | 6.7% |
| 3 separted | 73 | 0.6% |
| 4 widowed | 17 | 0.1% |
| 5 divorced | 0 | 0.0% |
| 6 Co-habitating | 8 | 0.0% |
| 7 Other | 1 | 0.0% |
| 8 2nd marriage | 31 | 0.2% |
| 9 Extr-marital preg. | 4 | 0.0% |

Sex of Baby Male 6726 (51.8%) Female 6252 (48.2%)
Liveborn Yes 12,848 (98.9%) No 146 (1.1%)
Stillborn Yes 140 (1.1%) No 12,848 (98.99%)
Congenital Abn. Yes 73 (0.6%) No 12,921 (99.4%)
Perinatal Death Yes 104 (0.8%) No 12,889 (99.2%) (1 cot death)
Neonatal Death Yes 22 (0.2%) No 12,958 (99.8%) (1 cot death)
Late Abortion Death Yes 34 (0.2%) No 12,960 (99.7%)

Table #1

Cutoffs for Dividing Weight Groups

| week | BMI | (+15%) | (-15%) |
|---|---|---|---|
| 10 | 2.224 | 2.559 | 1.890 |
| 11 | 2.225 | 2.559 | 1.891 |
| 12 | 2.228 | 2.562. | 1.894 |
| 13 | 2.235 | 2.570 | 1.900 |
| 14 | 2.245 | 2.582 | 1.908 |
| 15 | 2.257 | 2.596 | 1.918 |
| 16 | 2.270 | 2.611 | 1.930 |
| 17 | 2.285 | 2.628 | 1.942 |
| 18 | 2.302 | 2.647 | 1.957 |
| 19 | 2.319 | 2.667 | 1.971 |
| 20 | 2.337 | 2.688 | 1.986 |

Table #2

## Data for Median Weights at each Week of Gestation

| gest. age (weeks) | #cases | Median (kg) emp. | Median (kg) pred. | 5%tile emp. | 5%tile pred. | 95%tile emp. | 95%tile pred. |
|---|---|---|---|---|---|---|---|
| 10 | 1035 | 57.4 | 56.1 | 46.7 | 46.4 | 73.8 | 73.4 |
| 11 | 947 | 57.5 | 56.6 | 46.1 | 46.1 | 72.6 | 73.7 |
| 12 | 1036 | 55.9 | 57.0 | 46.1 | 46.0 | 77.8 | 74.1 |
| 13 | 953 | 57.5 | 57.4 | 46.1 | 46.1 | 70.7 | 74.5 |
| 14 | 942 | 57.4 | 57.8 | 45.5 | 46.2 | 74.3 | 74.8 |
| 15 | 795 | 57.4 | 58.2 | 45.8 | 46.4 | 75.8 | 75.2 |
| 16 | 716 | 58.0 | 58.6 | 46.7 | 46.7 | 75.3 | 75.7 |
| 18 | 827 | 59.6 | 59.4 | 47.3 | 47.5 | 77.8 | 76.5 |
| 19 | 1004 | 59.6 | 59.9 | 48.0 | 47.9 | 75.3 | 77.0 |
| 20 | 2568 | 59.9 | 60.3 | 48.2 | 48.4 | 77.4 | 77.4 |
| 21 | 1618 | 61.1 | 60.7 | 49.6 | 48.8 | 78.0 | 77.9 |
| 22 | 2334 | 61.4 | 61.1 | 49.6 | 49.3 | 79.4 | 78.3 |
| 23 | 1207 | 61.2 | 61.5 | 49.8 | 49.7 | 77.6 | 78.8 |
| 24 | 1352 | 62.0 | 61.9 | 50.3 | 50.1 | 80.0 | 79.2 |
| 25 | 690 | 62.0 | 62.3 | 50.5 | 50.6 | 79.1 | 79.7 |
| 26 | 902 | 62.3 | 62.7 | 50.6 | 51.0 | 78.5 | 80.1 |
| 27 | 551 | 62.8 | 63.1 | 50.4 | 51.3 | 80.2 | 80.6 |
| 28 | 962 | 63.1 | 63.6 | 51.1 | 51.7 | 81.5 | 81.1 |
| 29 | 1044 | 63.7 | 64.0 | 51.6 | 52.0 | 80.8 | 81.5 |
| 30 | 3938 | 64.9 | 64.4 | 52.4 | 52.3 | 82.3 | 82.0 |
| 31 | 2675 | 65.1 | 64.8 | 52.7 | 52.6 | 82.9 | 82.4 |
| 32 | 3052 | 65.3 | 65.2 | 53.0 | 52.9 | 82.9 | 82.8 |
| 33 | 1100 | 64.9 | 65.6 | 53.1 | 53.1 | 83.0 | 83.3 |
| 34 | 1100 | 65.0 | 66.0 | 52.7 | 53.4 | 83.9 | 83.7 |
| 35 | 1145 | 65.8 | 66.4 | 52.6 | 53.7 | 84.1 | 84.1 |
| 36 | 2975 | 66.7 | 66.9 | 53.8 | 54.0 | 84.2 | 84.4 |
| 37 | 6363 | 67.6 | 67.2 | 54.7 | 54.3 | 84.7 | 84.7 |
| 38 | 3450 | 67.7 | 67.7 | 55.0 | 54.7 | 85.2 | 85.1 |
| 39 | 2619 | 67.8 | 68.1 | 54.9 | 55.1 | 84.6 | 85.5 |
| 40 | 3353 | 68.6 | 68.5 | 55.5 | 55.6 | 86.0 | 85.8 |
| 41 | 1626 | 68.5 | 68.9 | 56.2 | 56.2 | 86.6 | 86.1 |
| 42 | 775 | 70.0 | 69.3 | 56.7 | 56.9 | 86.7 | 86.3 |

Table #3

emp.=empirical, derived from raw data
pred.=predicted, via polynomial regression

## Body Mass Index for Each Week of Gestation

| Week | #cases | Median emp. | Median pred. | 5%tile emp. | 5%tile pred. | 95%tile emp. | 95%tile pred. |
|---|---|---|---|---|---|---|---|
| 10 | 933 | 2.22 | 2.19 | 18.4 | 18.2 | 2.86 | 2.85 |
| 11 | 870 | 2.22 | 2.20 | 18.5 | 1.83 | 2.83 | 2.86 |
| 12 | 1135 | 2.25 | 2.22 | 1.87 | 1.85 | 2.94 | 2.88 |
| 13 | 890 | 2.23 | 2.25 | 1.86 | 1.86 | 2.85 | 2.89 |
| 14 | 877 | 2.24 | 2.25 | 1.84 | 1.87 | 2.90 | 2.91 |
| 15 | 742 | 2.25 | 2.27 | 1.88 | 1.89 | 2.91 | 2.93 |
| 16 | 672 | 2.25 | 2.28 | 1.86 | 1.90 | 2.91 | 2.94 |
| 17 | 850 | 2.27 | 2.30 | 1.89 | 1.91 | 2.95 | 2.96 |
| 18 | 764 | 2.31 | 2.32 | 1.93 | 1.94 | 3.01 | 2.97 |
| 19 | 949 | 2.32 | 2.33 | 1.93 | 1.94 | 2.98 | 2.99 |
| 20 | 2369 | 2.33 | 2.35 | 1.95 | 1.95 | 2.98 | 3.00 |
| 21 | 1548 | 2.37 | 2.36 | 1.97 | 1.97 | 3.00 | 3.02 |
| 22 | 2122 | 2.39 | 2.38 | 1.97 | 1.98 | 3.06 | 3.03 |
| 23 | 1129 | 2.40 | 2.40 | 1.99 | 1.99 | 3.02 | 3.05 |
| 24 | 1228 | 2.41 | 2.41 | 2.02 | 2.01 | 3.09 | 3.06 |
| 25 | 659 | 2.41 | 2.43 | 2.02 | 2.02 | 3.05 | 3.08 |
| 26 | 850 | 2.43 | 2.44 | 2.03 | 2.03 | 3.08 | 3.09 |
| 27 | 523 | 2.42 | 2.46 | 2.03 | 2.05 | 3.10 | 3.11 |
| 28 | 853 | 2.47 | 2.47 | 2.06 | 2.06 | 3.12 | 3.12 |
| 29 | 982 | 2.49 | 2.49 | 2.07 | 2.07 | 3.14 | 3.13 |
| 30 | 3666 | 2.52 | 2.51 | 2.10 | 2.09 | 3.17 | 3.15 |
| 31 | 2539 | 2.54 | 2.52 | 2.10 | 2.10 | 3.19 | 3.17 |
| 32 | 2772 | 2.54 | 2.54 | 2.12 | 2.11 | 3.19 | 3.18 |
| 33 | 1031 | 2.54 | 2.55 | 2.09 | 2.13 | 3.23 | 3.20 |
| 34 | 992 | 2.53 | 2.57 | 2.10 | 2.14 | 3.20 | 3.21 |
| 35 | 1066 | 2.59 | 2.59 | 2.14 | 2.15 | 3.20 | 3.23 |
| 36 | 2681 | 2.59 | 2.60 | 2.15 | 2.17 | 3.23 | 32.4 |
| 37 | 5988 | 2.63 | 2.62 | 2.19 | 2.18 | 3.26 | 3.26 |
| 38 | 3157 | 2.63 | 2.63 | 2.20 | 2.19 | 3.28 | 3.27 |
| 39 | 2425 | 2.64 | 2.65 | 2.20 | 2.21 | 3.25 | 3.29 |
| 40 | 3133 | 2.66 | 2.66 | 2.23 | 2.22 | 3.29 | 3.30 |
| 41 | 1506 | 2.67 | 2.68 | 2.23 | 2.23 | 3.35 | 3.32 |
| 42 | 742 | 2.73 | 2.70 | 2.24 | 2.25 | 3.37 | 3.33 |

Table #4

emp.=empirical, derived from raw data
pred.= value following regression

## Median BMI's- Medium Weight Group

| Gest. age (weeks) | #cases | Median BMI emp. | Median BMI pred. |
|---|---|---|---|
| 10 | 607 | 2.18 | 2.18 |
| 11 | 537 | 2.19 | 2.18 |
| 12 | 718 | 2.19 | 2.19 |
| 13 | 552 | 2.19 | 2.19 |
| 14 | 556 | 2.20 | 2.20 |
| 15 | 452 | 2.21 | 2.21 |
| 16 | 400 | 2.22 | 2.23 |
| 17 | 328 | 2.23 | 2.24 |
| 18 | 431 | 2.26 | 2.26 |
| 19 | 482 | 2.28 | 2.28 |
| 20 | 1231 | 2.30 | 2.30 |
| 21 | 650 | 2.32 | 2.32 |
| 22 | 955 | 2.35 | 2.34 |
| 23 | 544 | 2.37 | 2.36 |
| 24 | 520 | 2.39 | 2.38 |
| 25 | 226 | 2.37 | 2.40 |
| 26 | 265 | 2.41 | 2.42 |
| 27 | 112 | 2.43 | 2.44 |
| 28 | 209 | 2.47 | 2.45 |
| 29 | 371 | 2.48 | 2.47 |
| 30 | 1665 | 2.48 | 2.49 |
| 31 | 1077 | 2.50 | 2.50 |
| 32 | 1180 | 2.51 | 2.52 |
| 33 | 336 | 2.51 | 2.53 |
| 34 | 249 | 2.54 | 2.54 |
| 35 | 338 | 2.58 | 2.56 |
| 36 | 1108 | 2.58 | 2.57 |
| 37 | 2967 | 2.58 | 2.58 |
| 38 | 1328 | 2.61 | 2.60 |
| 39 | 1110 | 2.61 | 2.61 |
| 40 | 1458 | 2.63 | 2.63 |
| 41 | 747 | 2.63 | 2.64 |
| 42 | 332 | 2.67 | 2.66 |

Table #5

emp.=empirical, derived from raw data
pred.=predicted, via polynomial regression

Median BMI's- Overweight Group

| Gest. age (weeks) | #cases | Median BMI emp. | Median BMI pred. |
|---|---|---|---|
| 10 | 128 | 2.69 | 2.70 |
| 11 | 131 | 2.69 | 2.71 |
| 12 | 200 | 2.75 | 2.72 |
| 13 | 133 | 2.71 | 2.73 |
| 14 | 128 | 2.73 | 2.74 |
| 15 | 121 | 2.75 | 2.76 |
| 16 | 97 | 2.78 | 2.77 |
| 17 | 76 | 2.79 | 2.79 |
| 18 | 101 | 2.84 | 2.81 |
| 19 | 133 | 2.79 | 2.82 |
| 20 | 286 | 2.85 | 2.83 |
| 21 | 161 | 2.84 | 2.86 |
| 22 | 241 | 2.89 | 2.88 |
| 23 | 112 | 2.89 | 2.89 |
| 24 | 132 | 2.94 | 2.91 |
| 25 | 49 | 2.88 | 2.93 |
| 26 | 71 | 2.94 | 2.95 |
| 27 | 36 | 2.91 | 2.97 |
| 28 | 43 | 3.04 | 2.98 |
| 29 | 90 | 2.96 | 3.01 |
| 30 | 389 | 3.02 | 3.01 |
| 31 | 289 | 3.02 | 3.04 |
| 32 | 288 | 3.06 | 3.05 |
| 33 | 76 | 3.08 | 3.07 |
| 34 | 62 | 3.08 | 3.08 |
| 35 | 93 | 3.12 | 3.10 |
| 36 | 260 | 3.11 | 3.11 |
| 37 | 662 | 3.12 | 3.12 |
| 38 | 307 | 3.15 | 3.13 |
| 39 | 259 | 3.13 | 3.14 |
| 40 | 335 | 3.15 | 3.15 |
| 41 | 180 | 3.18 | 3.16 |
| 42 | 82 | 3.14 | 3.17 |

Table #6

emp.=empirical, derived from raw data
pred.=predicted, via polynomial regression

Median BMI's- Underweight Group

| Gest. age (weeks) | #cases | Median BMI emp. | Median BMI pred. |
|---|---|---|---|
| 10 | 22 | 1.78 | 1.75 |
| 11 | 31 | 1.76 | 1.77 |
| 12 | 26 | 1.79 | 1.78 |
| 13 | 26 | 1.78 | 1.80 |
| 14 | 32 | 1.79 | 1.81 |
| 15 | 16 | 1.79 | 1.83 |
| 16 | 30 | 1.83 | 1.85 |
| 17 | 15 | 1.84 | 1.86 |
| 18 | 21 | 1.87 | 1.88 |
| 19 | 26 | 1.92 | 1.90 |
| 20 | 79 | 1.90 | 1.92 |
| 21 | 48 | 1.98 | 1.93 |
| 22 | 75 | 1.96 | 1.95 |
| 23 | 30 | 1.96 | 1.97 |
| 24 | 27 | 2.01 | 1.99 |
| 25 | 9 | 2.01 | 2.00 |
| 26 | 14 | 1.98 | 2.02 |
| 27 | 9 | 2.02 | 2.04 |
| 28 | 14 | 2.01 | 2.05 |
| 29 | 22 | 2.12 | 2.07 |
| 30 | 99 | 2.10 | 2.09 |
| 31 | 75 | 2.11 | 2.10 |
| 32 | 65 | 2.11 | 2.12 |
| 33 | 33 | 2.21 | 2.14 |
| 34 | 20 | 2.18 | 2.16 |
| 35 | 23 | 2.24 | 2.17 |
| 36 | 64 | 2.17 | 2.19 |
| 37 | 190 | 2.21 | 2.21 |
| 38 | 74 | 2.23 | 2.22 |
| 39 | 65 | 2.22 | 2.24 |
| 40 | 93 | 2.26 | 2.26 |
| 41 | 47 | 2.28 | 2.27 |
| 42 | 21 | 2.19 | 2.29 |

Table #7

emp.=empirical, derived from raw data
pred.=predicted, via polynomial regression

Change in Body Mass Index (BMI) - Weight Groups

| interval (weeks) | Underwts. | Mediumwts. | Overwts. |
|---|---|---|---|
| 10 - 40 | .51 | .45 | .46 |
| 10 - 20 | .17 | .12 | .15 |
| 20 - 30 | .17 | .19 | .18 |
| 30 - 40 | .17 | .14 | .13 |
| 13 - 26 | .22 | .19 | .19 |
| 26 - 39 | .22 | .19 | .19 |

Table #8

Median BMI's- Optimum and Suboptimum Outcomes
Medium Weight Group

| Gest. age (weeks) | Optimum #cases | Optimum Median BMI emp. | Optimum Median BMI pred. | Suboptimum #cases | Suboptimum Median BMI emp. | Suboptimum Median BMI pred. |
|---|---|---|---|---|---|---|
| 10 | 607 | 2.18 | 2.18 | 109 | 2.16 | 2.13 |
| 11 | 537 | 2.19 | 2.18 | 108 | 2.11 | 2.13 |
| 12 | 718 | 2.19 | 2.19 | 125 | 2.13 | 2.13 |
| 13 | 552 | 2.19 | 2.19 | 109 | 2.10 | 2.13 |
| 14 | 556 | 2.20 | 2.20 | 94 | 2.14 | 2.14 |
| 15 | 452 | 2.21 | 2.21 | 106 | 2.16 | 2.15 |
| 16 | 400 | 2.22 | 2.23 | 83 | 2.13 | 2.16 |
| 17 | 328 | 2.23 | 2.24 | 70 | 2.20 | 2.18 |
| 18 | 431 | 2.26 | 2.26 | 86 | 2.23 | 2.20 |
| 19 | 482 | 2.28 | 2.28 | 111 | 2.23 | 2.22 |
| 20 | 1231 | 2.30 | 2.30 | 285 | 2.23 | 2.24 |
| 21 | 650 | 2.32 | 2.32 | 122 | 2.26 | 2.26 |
| 22 | 955 | 2.35 | 2.34 | 186 | 2.28 | 2.28 |
| 23 | 544 | 2.37 | 2.36 | 103 | 2.33 | 2.30 |
| 24 | 520 | 2.39 | 2.38 | 112 | 2.30 | 2.32 |
| 25 | 226 | 2.37 | 2.40 | 50 | 2.38 | 2.34 |
| 26 | 265 | 2.41 | 2.42 | 67 | 2.37 | 2.36 |
| 27 | 112 | 2.43 | 2.44 | 44 | 2.37 | 2.37 |
| 28 | 209 | 2.47 | 2.45 | 87 | 2.38 | 2.39 |
| 29 | 371 | 2.48 | 2.47 | 93 | 2.36 | 2.40 |
| 30 | 1665 | 2.48 | 2.49 | 341 | 2.43 | 2.41 |
| 31 | 1077 | 2.50 | 2.50 | 211 | 2.42 | 2.43 |
| 32 | 1180 | 2.51 | 2.52 | 201 | 2.44 | 2.44 |
| 33 | 336 | 2.51 | 2.53 | 106 | 2.46 | 2.45 |
| 34 | 249 | 2.54 | 2.54 | 123 | 2.41 | 2.46 |
| 35 | 338 | 2.58 | 2.56 | 144 | 2.48 | 2.47 |
| 36 | 1108 | 2.58 | 2.57 | 276 | 2.49 | 2.48 |
| 37 | 2967 | 2.58 | 2.58 | 417 | 2.49 | 2.49 |
| 38 | 1328 | 2.61 | 2.60 | 258 | 2.51 | 2.49 |
| 39 | 1110 | 2.61 | 2.61 | 152 | 2.51 | 2.51 |
| 40 | 1458 | 2.63 | 2.63 | 170 | 2.50 | 2.52 |
| 41 | 747 | 2.63 | 2.64 | 59 | 2.55 | 2.53 |
| 42 | 332 | 2.67 | 2.66 | 31 | 2.51 | 2.54 |

Table #9

emp.=empirical, derived from raw data
pred.=predicted, via polynomial regression

Interval Change in BMI--Medium Weight Group

| interval(wks.) | Optimum | Subopt. | Smokers | Non-smokers |
| --- | --- | --- | --- | --- |
| 10 - 40 | .45 | .39 | .46 | .46 |
| 10 - 20 | .12 | .11 | .13 | .13 |
| 20 - 30 | .19 | .17 | .19 | .19 |
| 30 - 40 | .14 | .11 | .15 | .14 |
| 13 - 26 | .23 | .23 | .21 | .22 |
| 26 - 39 | .19 | .15 | .20 | .21 |

Table #10

Median BMI's- Smokers vs. Non-smokers
Medium Weight Group

| Gest. age (weeks) | Smokers #cases | Smokers Median BMI emp. | Smokers Median BMI pred. | Non-smokers #cases | Non-smokers Median BMI emp. | Non-smokers Median BMI pred. |
|---|---|---|---|---|---|---|
| 10 | 181 | 2.14 | 2.13 | 435 | 2.19 | 2.18 |
| 11 | 206 | 2.15 | 2.13 | 339 | 2.19 | 2.19 |
| 12 | 293 | 2.17 | 2.15 | 432 | 2.20 | 2.19 |
| 13 | 235 | 2.14 | 2.16 | 338 | 2.20 | 2.21 |
| 14 | 236 | 2.16 | 2.17 | 329 | 2.22 | 2.22 |
| 15 | 215 | 2.19 | 2.19 | 257 | 2.22 | 2.23 |
| 16 | 185 | 2.16 | 2.20 | 227 | 2.23 | 2.25 |
| 17 | 166 | 2.21 | 2.22 | 181 | 2.24 | 2.26 |
| 18 | 205 | 2.20 | 2.23 | 237 | 2.28 | 2.28 |
| 19 | 249 | 2.26 | 2.25 | 251 | 2.29 | 2.29 |
| 20 | 579 | 2.26 | 2.26 | 705 | 2.29 | 2.31 |
| 21 | 284 | 2.28 | 2.28 | 404 | 2.33 | 2.33 |
| 22 | 418 | 2.31 | 2.30 | 569 | 2.37 | 2.35 |
| 23 | 246 | 2.36 | 2.31 | 320 | 2.38 | 2.37 |
| 24 | 255 | 2.31 | 2.33 | 283 | 2.42 | 2.39 |
| 25 | 132 | 2.38 | 2.35 | 116 | 2.38 | 2.40 |
| 26 | 150 | 2.39 | 2.37 | 135 | 2.44 | 2.42 |
| 27 | 59 | 2.34 | 2.39 | 64 | 2.50 | 2.44 |
| 28 | 106 | 2.40 | 2.41 | 135 | 2.48 | 2.46 |
| 29 | 176 | 2.43 | 2.42 | 219 | 2.51 | 2.48 |
| 30 | 730 | 2.45 | 2.44 | 977 | 2.49 | 2.50 |
| 31 | 511 | 2.48 | 2.46 | 652 | 2.51 | 2.51 |
| 32 | 484 | 2.47 | 2.47 | 704 | 2.53 | 2.53 |
| 33 | 170 | 2.45 | 2.49 | 190 | 2.53 | 2.55 |
| 34 | 158 | 2.43 | 2.51 | 134 | 2.59 | 2.57 |
| 35 | 190 | 2.52 | 2.52 | 199 | 2.58 | 2.58 |
| 36 | 502 | 2.52 | 2.54 | 652 | 2.60 | 2.60 |
| 37 | 1190 | 2.56 | 2.55 | 1633 | 2.61 | 2.61 |
| 38 | 604 | 2.57 | 2.56 | 799 | 2.61 | 2.62 |
| 39 | 473 | 2.55 | 2.57 | 645 | 2.64 | 2.63 |
| 40 | 600 | 2.58 | 2.59 | 856 | 2.65 | 2.64 |
| 41 | 282 | 2.62 | 2.60 | 443 | 2.63 | 2.65 |
| 42 | 137 | 2.62 | 2.62 | 201 | 2.68 | 2.66 |

Table #11
emp.=empirical, derived from raw data
pred.=predicted, via polynomial regression

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